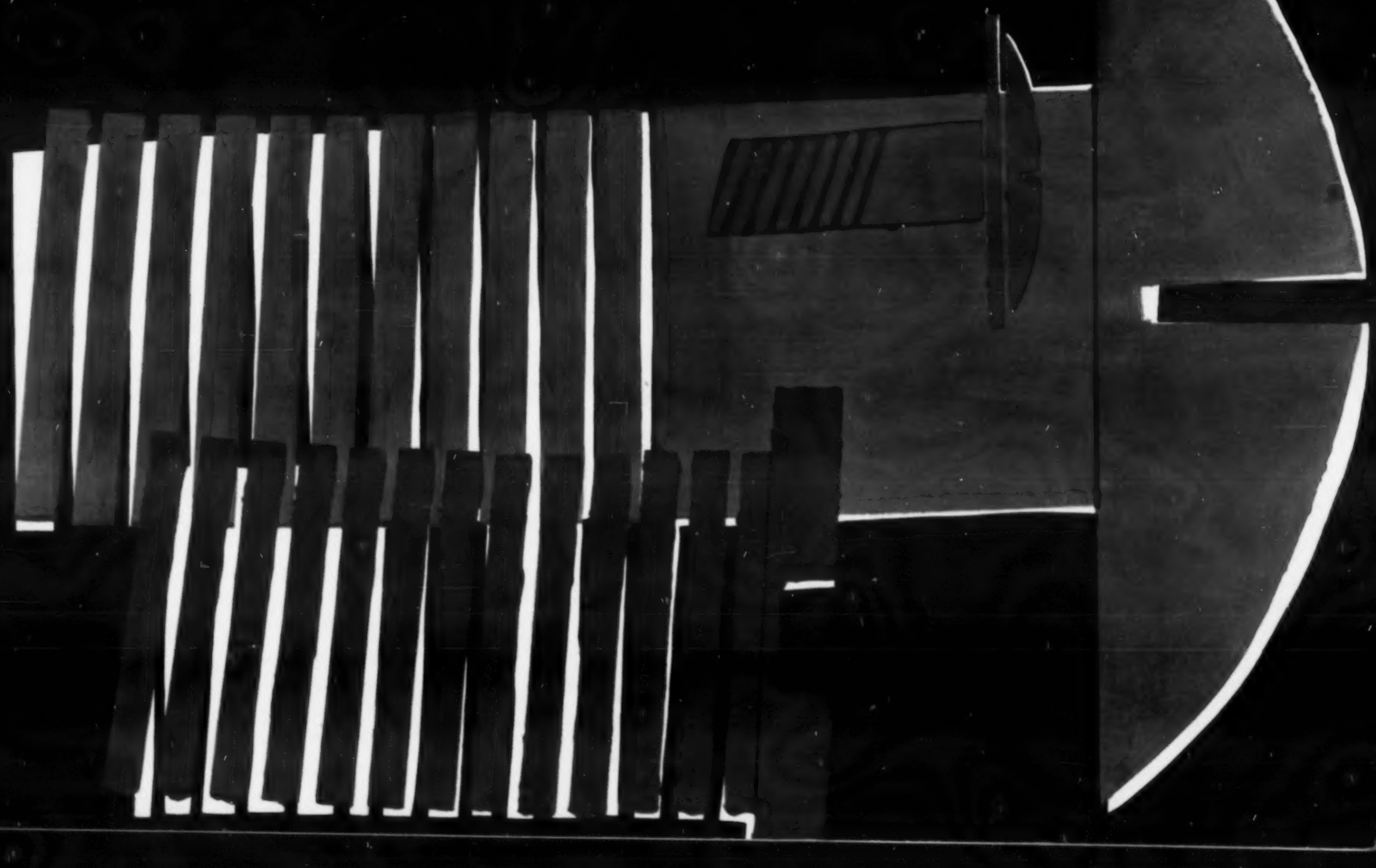
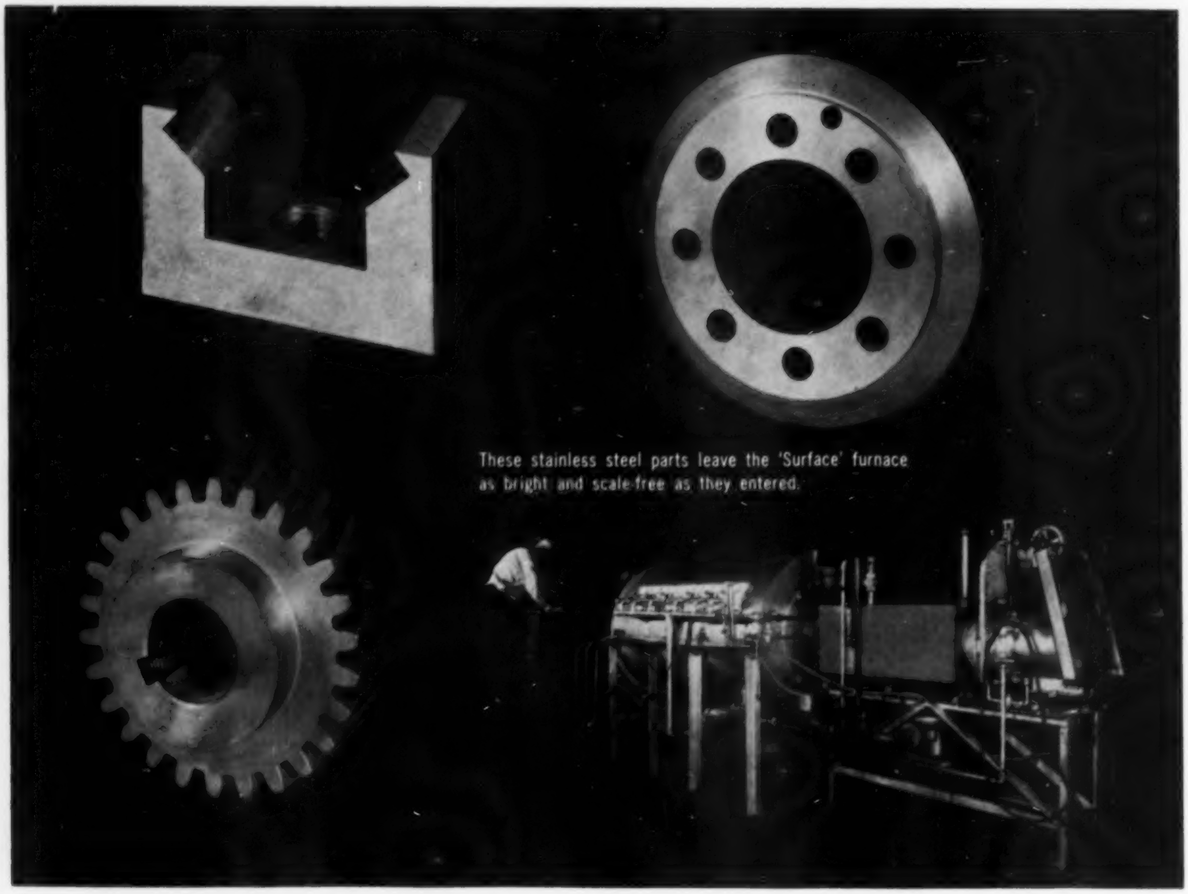
METAL PROGRESS

AUGUST 1956





bright hardened stainless sells!

you can really sell bright hardened stainless and other high alloy steels, because they save money for your customers.

this has been demonstrated by the people at Syracuse Heat Treat Co., Syracuse, N. Y. In the two years since they installed this 'Surface' high temperature muffle furnace, they have sold their customers savings—cost cut $1.87 on one part . . . hand stoning operation cut from 30 to 5 minutes on another . . . delivery in half the previous time . . . tighter specifications met.

and you earn yourself, as the Syracuse people found out, because the furnace delivers parts clean and bright, and eliminates costly, time-consuming descaling operations. The market is good for the premium product this furnace permits. Why not tap it now?

SEND FOR BULLETIN SC-173 • SURFACE COMBUSTION CORPORATION • 2377 DORR ST., TOLEDO 1, OHIO

Surface® Heat Treat, Steel Mill, Glass Divisions • Kathabar® Air Conditioning Division
Janitrol® Heating and Air Conditioning Division • Janitrol® Aircraft-Automotive Division

Surface®
HEAT TREATING EQUIPMENT

Metal Progress

Volume 70, No. 2

August . . . 1956

Cover by BARBARA RUBINSTEIN – a prizewinning entry in the annual competition at Cleveland Institute of Art

Table of Contents Continued on P. 3

METAL PROGRESS is published monthly by the AMERICAN SOCIETY FOR METALS. Publication office, Mt. Morris, Ill. Editorial, executive and advertising offices, 7301 Euclid Ave., Cleveland 3, Ohio. Subscription $7.50 a year in U.S. and Canada; foreign $10.50. Single copies $1.50; special issues $3.00 . . . The A.S.M. is not responsible for statements or opinions in this publication.

Requests for change in address should include *old* address of the subscriber; missing numbers due to "change of address" cannot be replaced. Claims for nondelivery must be made within 60 days of issue. No claims allowed for overseas subscribers. Entered as second-class matter at the Post Office in Mt. Morris, Ill.

The coding symbols refer to the ASM-SLA Metallurgical Literature Classification.

As I was saying...

It is really surprising the atomic growth of new chapters in the A.S.M. Some of them are the result of nuclear activity whereby they fission from the larger bodies.

The first real fission occurred in the annals of the Society some 25 years ago when the New Jersey contingent of the New York Chapter decided they would like to walk alone. They did it with remarkable success. Just recently a group in Long Island branched from New York and organized a chapter.

As we look back over the new chapters springing from the old, we find Detroit gave birth to four: Saginaw Valley, Toledo, West Michigan and Jackson.

Chicago, early in its career, assisted in the formation of the Calumet Chapter. Recently, the Chicago-Western Chapter has sprung full-grown from the parent body.

Last week's mail brought to the board a petition for the formation of a chapter in Wilmington, with more than 75% of the members currently belonging to the Philadelphia Chapter. We understand that another chapter is branching off from Philadelphia in the territory of Trenton, although the petition for a charter has not yet arrived at headquarters.

The Carolinas Chapter has been instrumental in the development of new chapters in the Old South and Savannah.

The Pittsburgh Chapter is fathering a new group in Beaver Valley, and Los Angeles is cooperating in the formation of a chapter in the San Fernando Valley.

It is very gratifying to note the fine spirit that is being exhibited by all the parent chapters, to a man. They have cooperated in every possible way, granting every known assistance, so that the new chapter is able to grow strong and healthy. No parent chapter has suffered from a fission. In every instance the parent has become a greater bulwark of education and help to the community it serves.

While the weather is warm, air-conditioning facilities have developed to the point where my biennial visits with chapter officers are progressing with speed and comfort. At these group meetings we invite the newly elected chairmen and vice-chairmen to meet at a central point (representatives of about ten chapters meet at each location) to discuss experience and plan the future work of the chapters. By the time this column reaches you, group meetings will have been held in Winston-Salem, Cincinnati, Boston, Philadelphia, Chicago, Kansas City, Cleveland, Rochester, Indianapolis, and Detroit. As the readers of the column know, the California and Pacific Northwest chapters (including Canada) were visited during the winter.

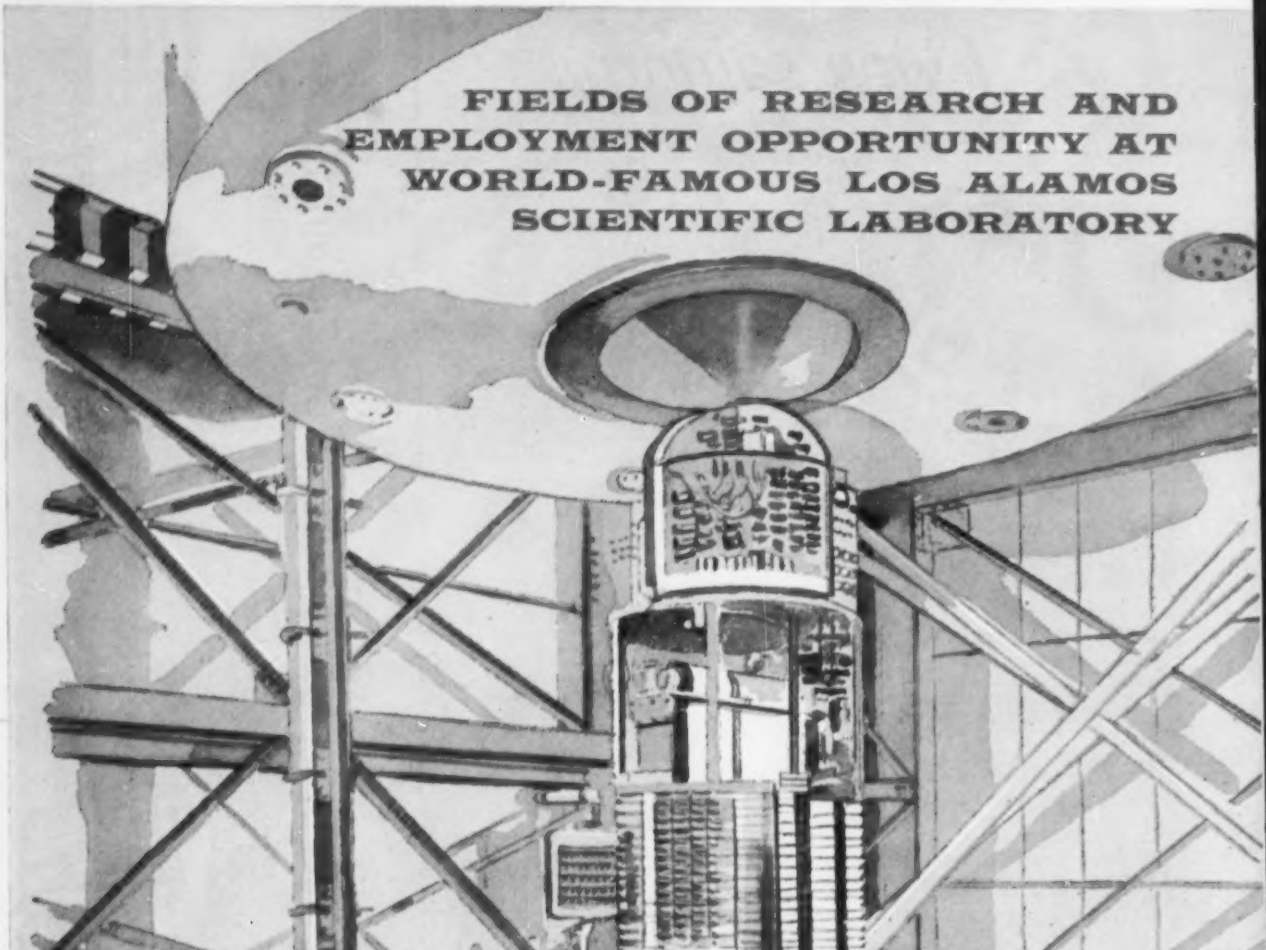
It is really a thrill to meet with the officers of our A.S.M. chapters and observe the spirit of enthusiasm and hard work they exhibit in the conduct of chapter business. There is no question at all that the strength of the A.S.M. lies in the strength of its chapters. One need only sit in a conference—such as has been my pleasure during the past few months—to realize that the A.S.M. is a mighty fortunate organization in having attracted to its service the high-caliber men who so faithfully serve the Society and its members.

Before signing off I wish to alert you to the Cleveland convention, which will be held Oct. 6 through 12. Those dates will be here before you know it, so you should make your plans now to attend. There will be top-notch technical papers and more than 450 exhibitors will display their products and processes for your observation.

Cordially yours,

Bill

W. H. Eisenman, *Secretary*
American Society for Metals



Los Alamos Scientific Laboratory is operated by the University of California for the U. S. Atomic Energy Commission

ductility . . .

Vollrath makes stainless steel washer tub in one deep draw

The Vollrath Company, Sheboygan, Wisconsin, makes a quality line of special stainless steel products for many industries including chemical, dairy, food processing and appliance.

One of the most interesting products, from a fabricating standpoint, is a stainless steel washer tub made for the Speed Queen Automatic Washer.

Vollrath craftsmen start with a circular blank of Republic ENDURO Stainless Steel, Type 430. Then, in a single operation, they draw the blank into a tub. What makes it unusual is the extremely deep draw in which the diameter of the blank is reduced 50%. This is proof of ENDURO's ductility.

But, uniform ductility is only one advantage of ENDURO. It offers a combination of mechanical, heat-resisting and corrosion-resisting properties that no other commercial metal can match. And it is not difficult to fabricate, just different.

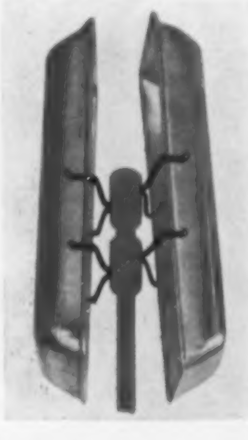
Republic produces ENDURO Stainless and heat-resisting steels in bars, slabs and billets, forging blanks, cold drawn shapes, plates, sheets, strip, tubing, tube rounds, wire and welding rod.

Our metallurgists and machining specialists will help you apply ENDURO to your product or process. There's no obligation. Mail the coupon if you would like one to call at your plant.

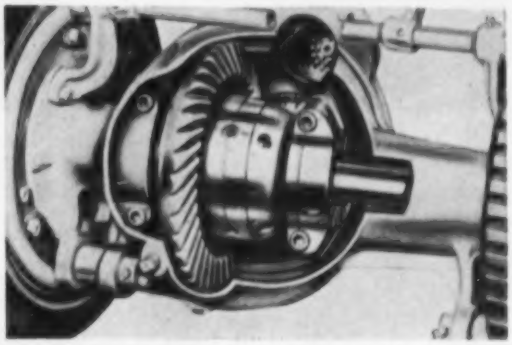
STEEL

and Steel Products

HERE'S PROOF OF MACHINABILITY — This spiral milled shaft is the heart of a ratchet-type screw driver. It bears the full load of the twisting operation. Excellent machinability of Republic Cold Drawn Steel helps the manufacturer achieve uniform high quality in each shaft. Cold drawing provides additional benefits in improved physical properties.



HERE'S PROOF OF CORROSION-RESISTANCE — A producer of ice trays and grids increased anodizing rack life 100 times by switching from aluminum to Republic Titanium. Its stubborn resistance to most forms of chemical attack, and total resistance to salt water make Republic Titanium an economical long-term investment. Investigate Republic Titanium for your parts that must withstand severe service.



HERE'S PROOF OF STRENGTH AND TOUGHNESS — This axle performs double duty. It drives a lift truck and bears the full weight of whatever is being lifted, including loads up to 100,000 pounds. By taking full advantage of Republic Alloy Steel's superior strength and resistance to fatigue, shock and stress, the manufacturer insures safety, extends equipment life, cuts maintenance and replacement costs.

REPUBLIC STEEL CORPORATION
Dept. C-2060
3188 East 45th Street • Cleveland 27, Ohio

☐ Have a stainless steel metallurgist call.

Send more information on:

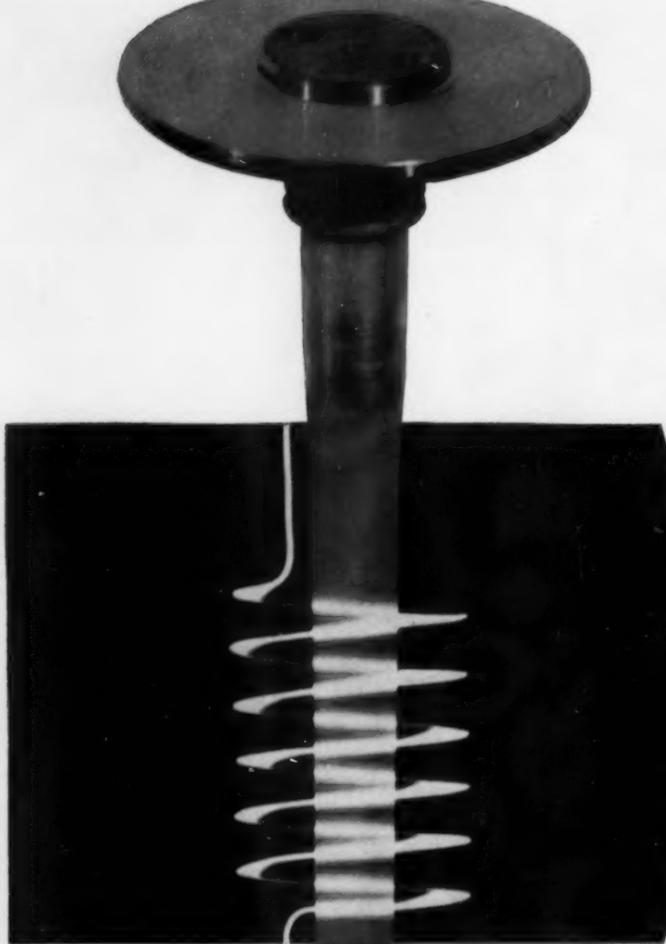
☐ ENDURO® Stainless Steel ☐ Cold Drawn Steels
☐ Titanium ☐ Alloy Steels

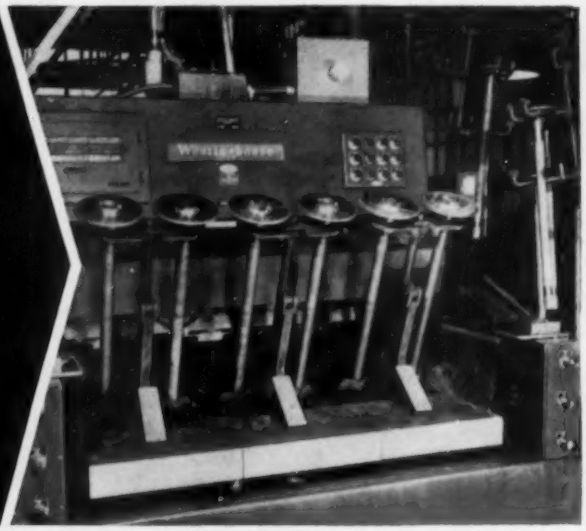
Name__________ Title__________

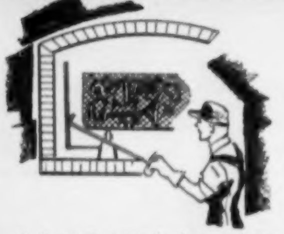
Company__________

Address__________

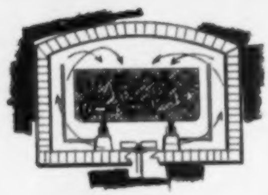
City__________ Zone____ State______



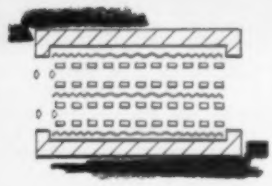




Safety! Extremely low voltage makes CORRTHERM elements completely safe. Let operator or work load bang it if they will. Neither element nor operator will be hurt.



CORRTHERM elements act as natural baffles to direct forced convection streams through the charge. The use of electric furnaces for carburizing and carbonitriding is now practical.



In continuous type furnaces CORRTHERM elements hang between lines of work as well as on side walls. Note how closer corrugations (at each end of element) compensate for incoming cold work and door losses.

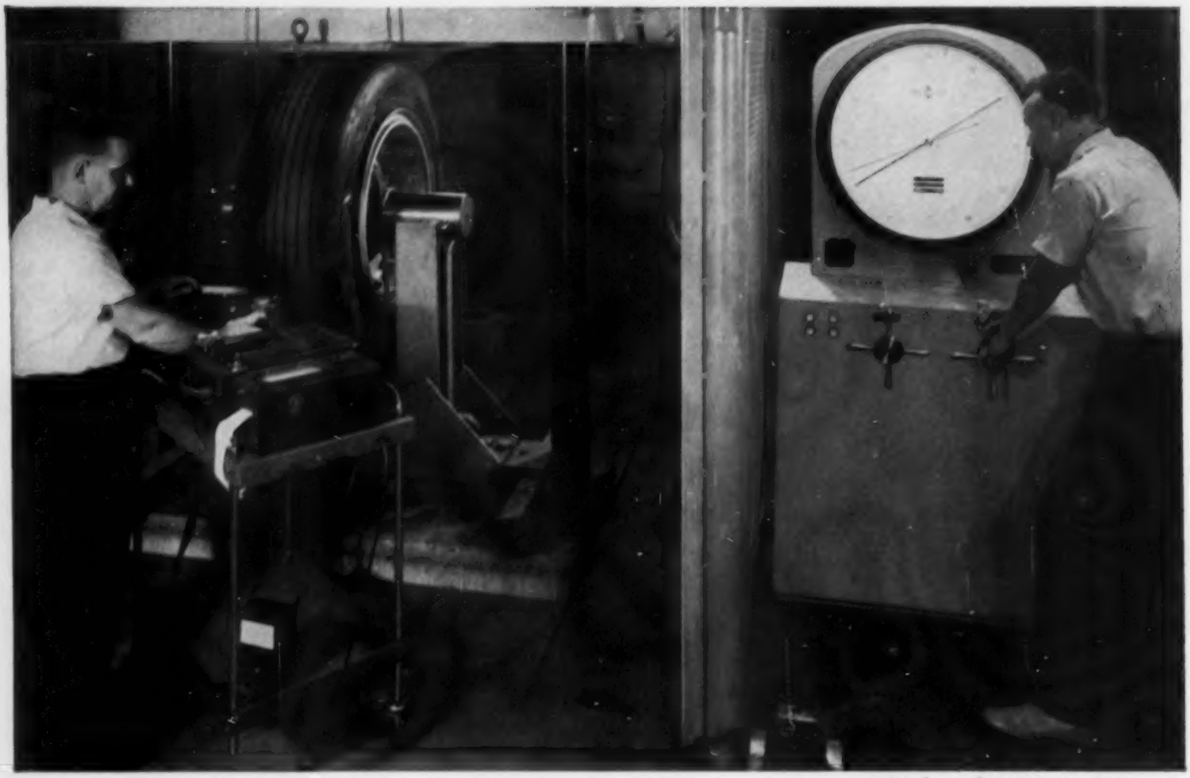


Photo Courtesy The B. F. Goodrich Company

Up to a ½ Million Pound "Squeeze" with an Olsen Super "L" at The B. F. Goodrich Co.

To ensure complete safety, The B. F. Goodrich Company subjects entire aircraft wheel assemblies to tortuous forces of compression far in excess of any encountered in service. The instrument of this "life saving" torture is a 500,000 lb. capacity Olsen Super "L" Compression Testing Machine.

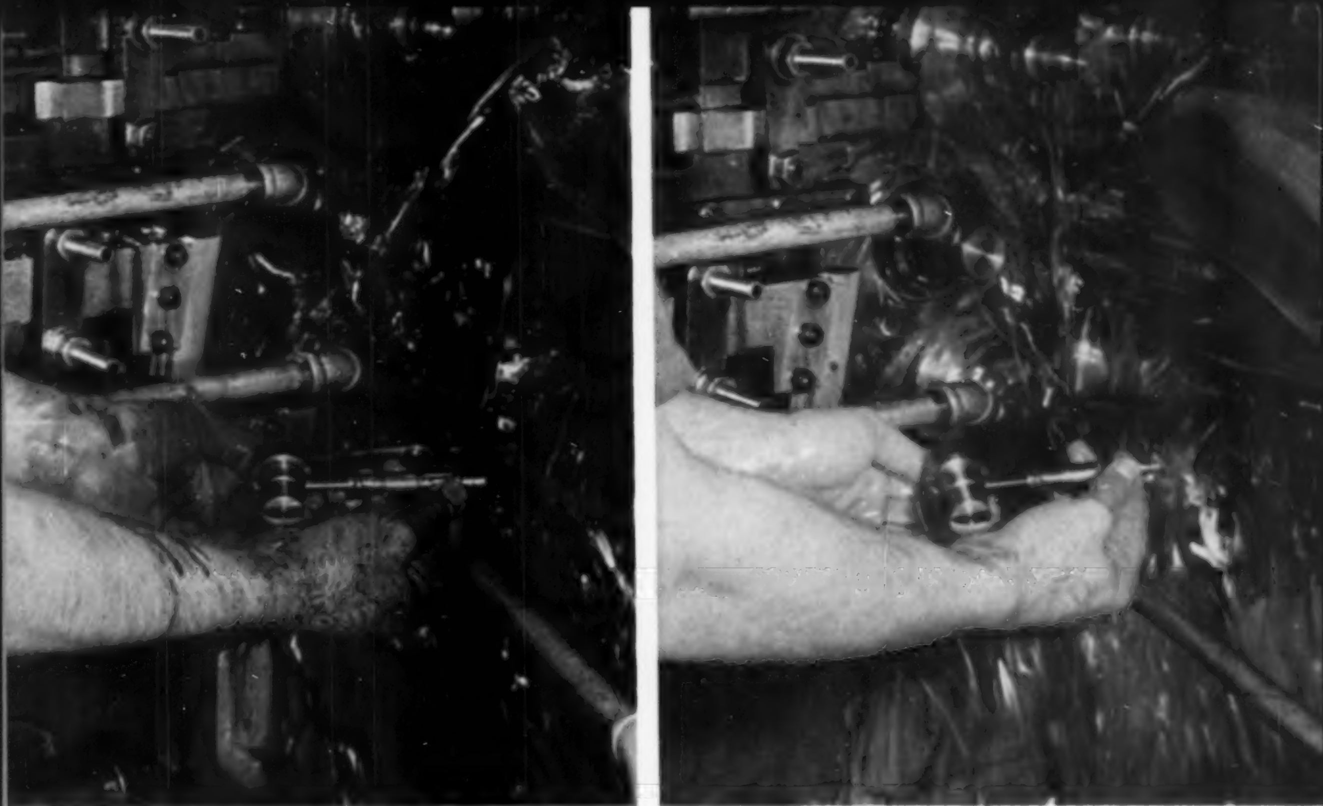
In spite of its size and capacity, this giant Olsen hydraulic machine offers the same operating ease and accuracy of all Olsen Super "L's"—including the SelecTrange Indicating System and a minimum of 50 to 1 spread of testing ranges. With a flip of the SelecTrange switch, the operator can instantly change ranges during test—no need to "calculate" the range capacity beforehand. All ranges have the same zero setting. Loads are clearly indicated on the large, 28-inch illuminated SelecTrange dial. Loading speeds are infinitely variable from zero to the capacity of the machine. These and many other exclusive features account for the unmatched superiority of Olsen Super "L" Compression and Universal Testing Machines.

It will pay you to get the facts about the complete line of Olsen Super "L's". Write today for Bulletin 47.

Trademark Reg. U.S. Pat. Off.

TINIUS OLSEN
TESTING MACHINE COMPANY
2030 EASTON ROAD • WILLOW GROVE, PA.

Testing and Balancing Machines



Black cutting oil (left) makes close control difficult. Operators dislike dirty operating conditions it creates. Close control is easier and workers are happier with transparent Sunicut cutting oil (right).

WHY USE A BLACK CUTTING OIL WHEN YOU DON'T NEED IT?

Sunicut oils give you better visibility without sacrificing machining efficiency.

When trying to maintain close control over machines producing precision parts, operators can be handicapped by "black-oil blindness". It is hard to see the tools, the workpiece, and the finishes. Checking close tolerances is difficult when the graduations on micrometers and gauges are obscured.

Worse still, as the operator sees it, are the dirty working conditions caused by dark oils. His clothes get saturated with hard-to-remove stains, and his hands are black from one end of the shift to the other.

Transparent Sunicut oils help keep your operators happy and will make close control easier ...and transparent Sunicut oils will do the job with no sacrifice in machining speed or finishes.

To get the full story on Sunicut oils, see your local Sun representative, or write SUN OIL COMPANY, Philadelphia 3, Pa., Dept. I-41.

SUNOCO ®

INDUSTRIAL PRODUCTS DEPARTMENT

SUN OIL COMPANY PHILADELPHIA 3, PA.

© SUN OIL CO.

IN CANADA: SUN OIL COMPANY LIMITED TORONTO AND MONTREAL

P&H LOW-HYDROGEN ELECTRODES

Cut Rod Cost 80%

— free report shows how

If you have tough jobs that require high strength welds, stainless steel rods are NOT the only answer. In fact, you can save up to 80% of stainless steel rod costs, by using P&H low-hydrogen electrodes. In addition, P&H low-hydrogen electrodes meet rigid tests for use with problem steel.

In the complete, impartial report offered here, you will find that P&H low-hydrogen electrodes save you money in many ways. Yet they reduce weight and make better products. There's a lot more information in this report. Read about actual tests for production quality, quality control, impact tests, supervision, and many other operations.

Send in coupon today for FREE report!

HARNISCHFEGER
MILWAUKEE 46, WISCONSIN

SEND IN COUPON TODAY FOR **FREE** REPORT!

HARNISCHFEGER CORPORATION
Welding Division
4549 W. National Avenue, Milwaukee 46, Wis.
Attention: W. R. Stephens, Sales Manager
I am interested in Report No. 5409.
Please send me my copy.

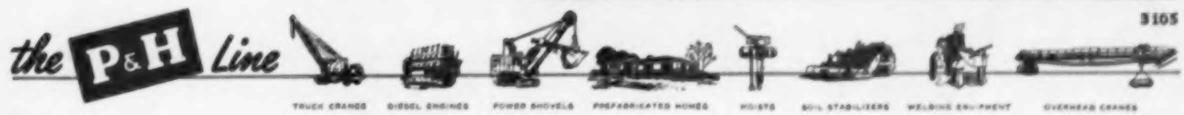
Name__________ Title__________

Company__________

Company Address__________

City__________ (___) State__________

3105

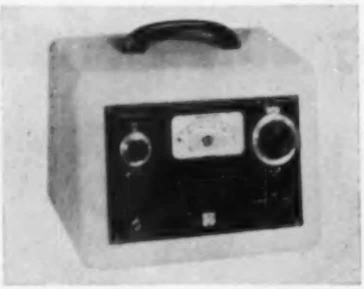


P&H welding equipment is manufactured and sold in Canada by REGENT EQUIPMENT MANUFACTURING COMPANY LTD., 455 King Street West • Toronto, Ontario, Canada

APPLICATION and EQUIPMENT new products

Corrosion Tester

A new instrument to measure the rate of corrosion in all types of metals subjected to the corrosive effects of various liquids or gases has been announced by Labline, Inc. The corrosion tester is a sensitive electronic Wheatstone bridge circuit. Probes have one protected corrosion strip and one exposed corrosion strip.

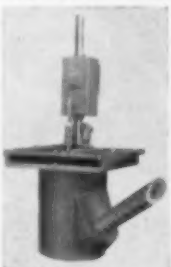


Automatic temperature compensation is obtained from the protected strip. The corrosion on the exposed strip causes the meter to indicate directly in micro-inches of corrosion. Probes holding the protected and unprotected metals are available in all types, for long or short test periods, for high or low temperature testing and for any service.

For further information circle No. 287 on literature request card, page 48-B.

Automatic Ladling Unit

A new ladling unit for aluminum which makes possible fully automatic processing of many types of castings has been announced by the Lindberg-Fisher Div., Lindberg Engineering Co. The unit is manufactured of special refractory materials, and is so arranged that the molten metal being ladled cannot come in contact with any metal structure. The basic pump has no moving parts, check valves or other devices. The automatic ladling unit operates on the principle of a pressurized chamber, the size of the shot depending upon both the time of pressure application and the pressure. Ladled metal is withdrawn from beneath the surface of the bath.



For further information circle No. 288 on literature request card, page 48-B.

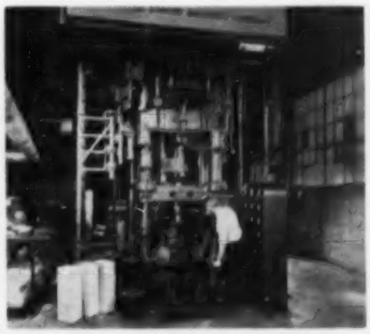
Refractory Cement

A new aluminum oxide cement has been announced by Electro Refractories & Abrasives Corp., to provide a more heat-resistant, longer-lasting lining for indirect arc-type electric furnaces. The aluminum oxide is said to hold up much better under high temperatures and slag attack than the mullite-base cements commonly used in these furnaces for melting ferrous and nonferrous alloys. The linings weigh from 500 to 1000 lb. The material can also be used for patching existing furnace linings.

For further information circle No. 289 on literature request card, page 48-B.

Powdered Metal Press

A new 300 ton hydraulic press for use in compacting parts from metal powders has been announced by the



United States Graphite Co. The press, which weighs 50 tons, is fully automatic and possesses multiple action features which permit the pressing of parts having a difficult H shape cross-section or other unusual design details. It was designed and built by Baldwin-Lima-Hamilton.

For further information circle No. 290 on literature request card, page 48-B.

Chromium Plating

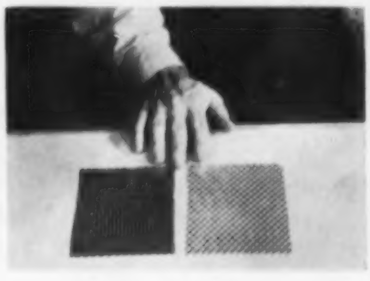
A new large capacity chromium plating unit especially designed to plate large size metal forming and plastic molding dies has been announced by the Dawson Corp. The unit has a plating tank 15 by 30 by

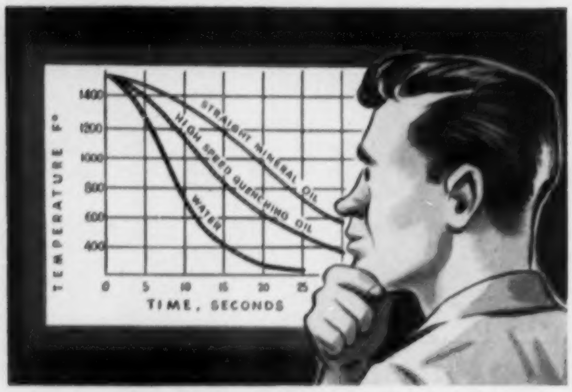
30 in. It is equipped with two 3000 watt electric immersion heaters and a heavy gage steel water jacket which provide accurate control of the plating bath through an adjustable thermostatic temperature control. The fully equipped rectifier, which provides a 300 amp. d.c. output to the plating bath, operates on a standard 200-volt, 3-phase, 60-cycle, a.c. connection.

For further information circle No. 291 on literature request card, page 48-B.

Brazing Strip

A new form of silver brazing alloy—expanded and rolled strip—has been announced by Handy & Harman. The principal advantage of the expanded strip is weight reduction, which is of particular importance in assemblies for aviation service, such as honeycomb structures, propeller





1. Quenching Speed. There are two basic types of quenching oils...straight mineral oils and compounded high-speed oils. If you can get the microstructure and hardness you need and have no distortion problems with a straight mineral oil, then it's the type to use. If you're not getting the results you want, increased agitation may help. If increased agitation doesn't help, or isn't practical, you should use a high-speed oil.

2. Naphthenic vs. Paraffinic. Both types of oil are used for quenching. Both have their own inherent advantages. Naphthenic oils keep oil coolers cleaner when the temperature of the oil doesn't exceed 150 F. A fully dewaxed paraffinic oil gives the most satisfactory results at temperatures over 150 F. As a rule, when all other operating factors are equal, the temperature of your oil bath tells you which type of oil to use.

What's the difference in quenching oils?

3. Thermal Stability. This is the biggest single factor influencing the useful life of a quenching oil. The higher the temperature of the oil bath, the shorter the life of any given oil. As mentioned before, at temperatures over 150 F it takes a stable, fully dewaxed paraffinic oil to give the most satisfactory results. For maximum useful life at temperatures over 200 F you will probably need a specially inhibited quenching oil.

4. Other Considerations. When quenching from a salt pot, use a straight mineral oil. Don't use an oil containing lard oil or other vegetable or animal fats. The salt carried into the oil on the parts will cause these fats to saponify and form oil-thickening grease. For bright quenching, experience shows that a straight mineral oil will give the best over-all results. For the most part, a straight oil will give cleaner parts longer.

These facts are nothing more than a guide to help you select the quenching oil best suited to your particular needs. To arrive at the final answer, there's no substitute for experience. Sun's representatives, backed up by Sun's metallurgical staff, have that experience. And, they're backed up by a *complete* line of quenching oils, paraffinic or naphthenic, regular or high-speed, straight or inhibited. Sun makes them all. For more information, see your Sun representative or write SUN OIL COMPANY, Philadelphia 3, Pa., Dept. MP-8.

INDUSTRIAL PRODUCTS DEPARTMENT

SUN OIL COMPANY

PHILADELPHIA 3, PA. ©SUN OIL CO.

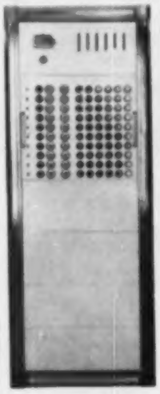
IN CANADA: SUN OIL COMPANY LIMITED, TORONTO and MONTREAL

SUNOCO

blades and other large components customarily assembled by brazing. The expanded silver alloy is produced by expanding conventional solid strip and then rolling the resulting grid down to the specified uniform thickness. Expanded strips up to 12 in. wide in precision thicknesses down to 0.003 in. can be supplied.
For further information circle No. 292 on literature request card, page 48-B.

Fatigue Testing

An automatic program controller for Baldwin-Sonntag fatigue testing machines has been announced by Baldwin-Lima-Hamilton Corp. Load levels can be set on any value up to machine capacity. On the SF-1-U machine the rate at which the load, either static or dynamic, can be changed by the programmer is approximately 500 lb. per min. Duration of the application of each of the ten load levels is determined by an electronic cycle counter which can be set by means of six decade (10-position) switches. Sequencing is determined by a three-position sequence selector switch. In the first position, the 10 load steps are repeated in the order of 1 to 10. The second position takes the steps from 1 to 10, then 10 to 1 successively. The third position provides for random order of load steps, permitting 20 selections of load levels in any order and sequencing them. The number of sequences is preset on a sequence counter which provides for a maximum of 9999 sequences.



For further information circle No. 293 on literature request card, page 48-B.

Chromium Plating Additive

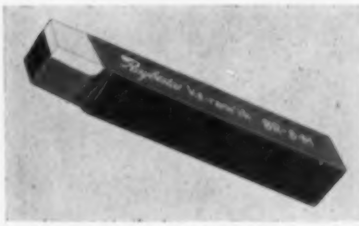
A chromium plating additive has been announced by the Chromium Chemicals Div. of Diamond Alkali Co. The new catalyst is designed for both decorative and hard-chromium plating applications. In replacing a portion of the sulfate used in conventional chromium plating solutions, Diamond CPA 1800 is reported to speed-up and simplify chromium-plating operations. Principal benefits claimed include faster plating, broader operating range of plating solution, and greater covering power. CPA 1800 is also claimed to make possible the electrodeposition of brighter and harder chromium coatings, to simplify anoding in hard-chromium applications, and to improve the metallurgical characteristics of chromium plate.
For further information circle No. 294 on literature request card, page 48-B.

Core Paste

A new Fastick liquid core paste for foundry use has been announced by Frederic B. Stevens, Inc. The features of the original Fastick which have been retained are high tensile strength, low gas evolution, fast drying, low cost and uniform ready-to-use packaging. The new product is more viscous and the nonsettling feature has been improved. Fastick is a replacement for clamps and backing substance with shell and process mold halves, as well as resin bonded and conventional sand cores.
For further information circle No. 295 on literature request card, page 48-B.

Ceramic-Tipped Tool

A new ceramic-tipped cutting tool has been announced by Raybestos Div. of Raybestos-Manhattan, Inc. The oxide-base ceramic tip is bonded to a steel shank; ordinarily ceramic bits are clamped in a holder. The Keramik cutting tool is being offered



in a standard size of ½ by ½ by 3½ in. with a lead angle of 7 deg. With this tool no cutting oils are necessary. The cutting tip runs cool, and chips will not weld to it. Because of low thermal conductivity, there is no build-up on the cutting edge and no cratering. In addition, the Keramik cutting tool is nonabsorbent and unaffected by corrosion.
For further information circle No. 296 on literature request card, page 48-B.

Flaw Detection

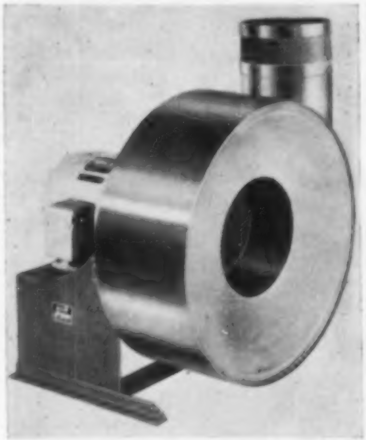
A new high resolving transducer for detection of small flaws close to the specimen surface has been announced by the Industrial and Scientific Products Div. of Curtiss-Wright. It will also differentiate between two defects in the same area. When a 10 Mc/s, ¾ in. dia., high resolution transducer is used with a suitable instrument, it is possible to detect a round plane flaw 0.0017 sq. in. in

area at a distance of only 0.1 in. below the top surface of an aluminum specimen.

For further information circle No. 297 on literature request card, page 48-B.

Turbo Blowers

A new line of turbo blowers for supplying air to gas and oil burners has been announced by Hauck Mfg. Co. The blowers are equipped with aluminum impellers and hubs in balanced impeller assemblies. Blower casings are of fabricated steel with



spun steel head having circular reinforcing rings. They are driven by standard open-frame ball-bearing motors. Blowers are made in a large number of sizes from 250 c.f.m. at 8 oz. pressure to 2650 c.f.m. at 24 oz. pressure.

For further information circle No. 298 on literature request card, page 48-B.

Electronic Potentiometer

A new electronic potentiometer, equipped with a pneumatic transmitter which sends a 3 to 15 psi. signal proportional to the measured

variable, has been announced by the Bristol Co. The transmitter is available in either potentiometer or bridge circuits, and will measure any variable which can be translated into an electrical quantity. It then converts the measurement into a universal 3 to 15 psi. pneumatic signal for transmission to a remote pneumatic indicator or recorder or automatic controller. It is possible to present measurements such as speed, viscosity, pH and resistance, along with more conventional measurements.

For further information circle No. 299 on literature request card, page 48-B.

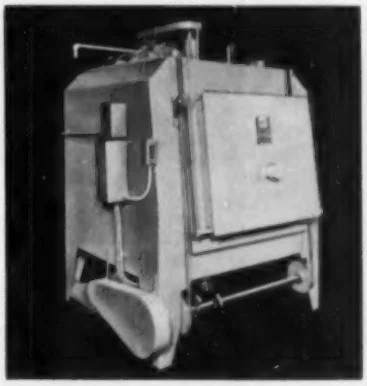
Lacquer

Fidelity Chemical Products Corp. has announced a new multiple purpose lacquer for metals. This new coating saves time during the coating operation by eliminating the need for switching from one lacquer to another when a different metal is to be finished. Clear lacquer No. 100 is colorless and has good adhesion. It forms a tough film which offers resistance to perspiration, corrosion, stain spotting, sulphur and heat and cold.

For further information circle No. 300 on literature request card, page 48-B.

Heat Treating Equipment

A new radiant tube, clean hardening furnace has been announced by Standard Fuel Engineering Co. It is also recommended for annealing, carburizing and for other atmosphere work. Vertical alloy radiant tubes are easily replaced from the top of the furnace. A high velocity alloy fan for recirculating the atmosphere is



located in the roof of the unit. Through the use of roller chains and sprockets, the door is raised and lowered from a drive located at the base of the furnace. The door, although fully sealed with asbestos gaskets, is in addition inclined to provide a natural friction seal. A gas curtain is provided and its operation is automatic.

For further information circle No. 301 on literature request card, page 48-B.

Foundry Tests

The Harry W. Dietert Co. has announced a precision testing device for making the standard American Foundrymen's Society clay determination test. This procedure calls for the removal of all particles which

High Frequency Furnaces. Norton MAGNORITE cement is engineered to provide maximum heats per lining. It gives extra long service life at temperatures to 3250°F, its high-rammed density resists metal penetration, erosion and chemical attack, and it is free from shrinkage cracks.

Low Frequency Furnaces. Foundries melting nonferrous metals and malleable iron report longer life from linings of Norton ALUNDUM cement. This high-melting, long-lasting cement is also prescribed for use in holding ladles and desulphurizing ladles.

ON TIME!

...with melt after melt

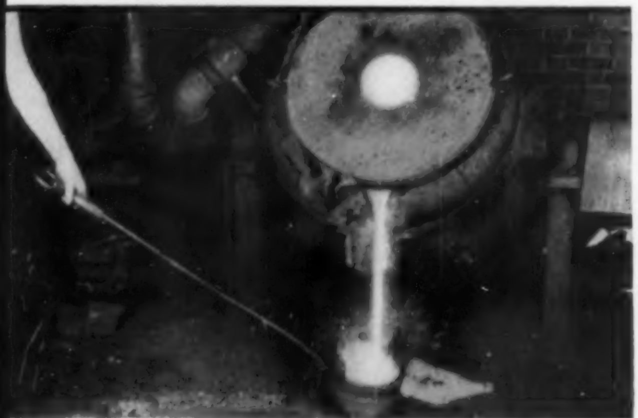
Norton Refractory R's help maintain hot metal schedules, reduce shut-downs, in your furnaces

Norton ALUNDUM*, CRYSTOLON*, MAGNORITE* and FUSED STABILIZED ZIRCONIA refractory materials are *engineered* for longer, lower cost service — and *prescribed* for better processing in many foundry applications.

For R's that will improve your own processing call in your Norton Refractories Engineer. Or write to NORTON COMPANY, Refractories Division, 327 New Bond Street, Worcester 6, Mass. *In Canada:* A. P. Green Fire Brick Co., Ltd., Toronto 5, Ontario.

*Trade-Marks Reg. U. S. Pat. Off. and Foreign Countries

Cupola Furnaces. For back slagging cupolas the Norton R is CRYSTOLON slag hole blocks. For capping the notch and lining the slag chute in front slagging cupolas, use CRYSTOLON bricks and cement. CRYSTOLON material is extremely resistant to attack by cupola slags thus providing needed protection in these critical areas.



Crucible Furnaces. Both the cover of this tilting crucible furnace and its cement lining are made of CRYSTOLON refractory material, engineered for the user's particular needs. CRYSTOLON linings offer effective protection against flame erosion and thermal shock in many different furnace applications.

NORTON

REFRACTORIES

Engineered... R ...Prescribed

Making better products... to make your products better

NORTON PRODUCTS: Abrasives • Grinding Wheels • Grinding Machines • Refractories
BEHR-MANNING PRODUCTS: Coated Abrasives • Sharpening Stones • Behr-cat Tapes

settle in water at a rate of less than 1 in. per min. The Autoclay is fully automatic, incorporating two solenoid valves for filling and syphoning, an electronic control device to govern the height of water in the container, and a relay sequence circuit to control the timing and initiate the individual operations. The syphoning and filling of the container require no attention from the operator as these operations are completely automatic. Agitation takes place every time the wash jar is refilled.
For further information circle No. 302 on literature request card, page 48-B.

High Vacuum Pump

Kinney Mfg. Div. has announced a new small version of its KMB two-stage mechanical booster high vacuum pump. The new model maintains uniformly high pumping speeds over a wide range of pressures and, since no liquid sealant is used in the first stage, delivers clean high vacuum. Power requirements are low. The unit consists of a water-cooled, lobe type rotor pump and motor and an air-cooled compound pump and motor. A baffled interstage connection is provided between the two pumps and both pumps and motors

are mounted on a common base. The unit operates automatically from atmospheric pressure down to 0.1 micron (0.001 mm. Hg) McLeod. After the compound pump roughs the system from atmospheric pressure to 50 mm. Hg, an automatic control sets the high speed lobe unit in operation and closes the integral bypass valve. A pumping speed of 150 c.f.m. is maintained over a broad pressure range from 200 to 3 microns. At 0.1 micron, pumping speed is 95 c.f.m.
For further information circle No. 303 on literature request card, page 48-B.

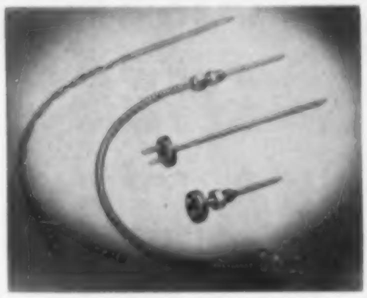
Combustion Tube Furnace

A new 4 kw. electric resistance element furnace accommodating one combustion tube up to 5 in. o.d. with maximum furnace temperature of 2750° F. is offered by Laboratory Equipment Div. of Lindberg Engi-

neering Co. In addition to its use as a standard tube furnace, the unit can be easily modified for use as a high temperature pot furnace or a constant temperature source for optical calibrations. Heat is supplied by eight silicon carbide heating elements having an effective heating length of 8 in. The large size tube allows use of furnace for production runs of small parts and is available with water jacketed Inconel tube assembly for heat treating applications up to 2150° F. requiring protective atmosphere.
For further information circle No. 304 on literature request card, page 48-B.

Miniature Thermocouples

Thermo Electric Co. has announced an expanded line of miniature protected thermocouples. Constructed with stainless steel protection tubes, these units were especially designed for use in gases and liquids highly corrosive to thermocouple materials. Because of their small size and weight, they are also well suited to pilot plant and other limited space applications. They are calibrated in iron-constantan, copper-constantan and chromel-alumel with three

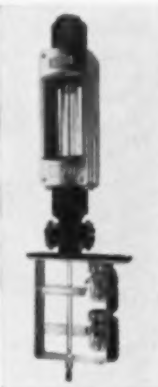


temperature ranges from −300 to +1600° F. By welding the hot junction directly to the protection tube both sensitivity and rapid response have been retained. Outer diameter

of the tubes ranges from 1/16 to ¼ in.
For further information circle No. 305 on literature request card, page 48-B.

Flow Alarm

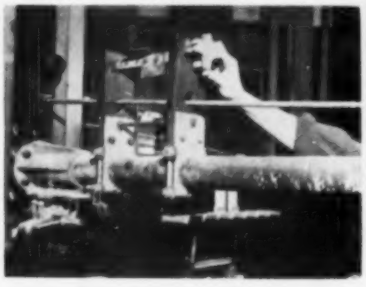
A flow alarm which provides vibration-proof operation has just been announced by Fischer & Porter Co. It uses two snap-action electrical contacts, hermetically sealed in a glass tube, which are drawn together to set off the alarm by passage of a magnetic float extension rod. The switch can be positioned in the mounting frame either above or below the magnet in the float extension rod to give a signal for either high or low limits of flow. The most important application for the flow alarm is in water or oil cooling lines for large machines.



For further information circle No. 306 on literature request card, page 48-B.

Automatic Finishing

A new bypass mechanism automatically controlling nine or more complete metal finishing processes on a single anodizing or electroplating machine has been announced by the Hanson-Van Winkle-Munning Co. Control is from a dial on the carrier arm that moves parts through proc-



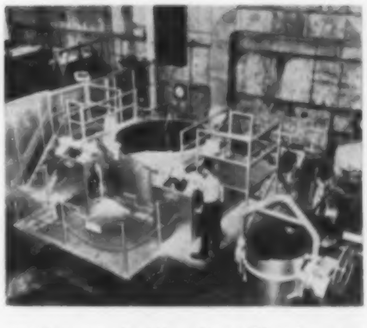
essing tanks. As unfinished parts are loaded on the carrier, the machine operator sets the dial for the processing steps through which the load is to move. Automatic conveying does the rest, lowering parts into the prescribed tanks, bypassing others, according to the dial settings. A series of limit switches and solenoid-operated setdown flippers control the action of the carrier.
For further information circle No. 307 on literature request card, page 48-B.

Grinding Compound

A new compound for diamond wheel grinding of carbide tools and other specialized grinding operations has been announced by the International Chemical Co. The high detergency of this new coolant eliminates gum formation on the grinding wheel and table which would retard free hand movement in off-hand grinding operations. It also precipitates grinding dust quickly and completely, regardless of the amount of stock removed. Compound No. 48 is an amine nitrite-type concentrate which dissolves in water to form a stable, transparent solution at all working concentrations. It can be re-used and has anti-rust properties that provide temporary protection.
For further information circle No. 308 on literature request card, page 48-B.

Kirksite Melting Furnace

A nose-tilting Kirksite melting furnace with 25,000 lb. capacity, 76 in. in diameter by 37 in. deep, has been announced by Bellevue Industrial Furnace Co. The nose-tilting feature eliminates the necessity of a deep pit, since the ladle rests on the same floor level as the furnace. This melting furnace will remelt large obsolete scrap dies without the necessity of



cutting up the dies first. The furnace has remelted 200,000 lb. of obsolete scrap dies weighing 18,000 to 19,000 lb. each in 4 days. Ten-ton dies have been poured.
For further information circle No. 309 on literature request card, page 48-B.

Electrolytic Salt

Virgo® electrolytic salt for cleaning gray iron castings has been announced by Hooker Electrochemical Co. Containing a new additive, the salt renders such castings and related materials, free of sand, scale, graphite and other surface impurities. The new salt is for use in those processes involving the molten bath operated in the 900° F. range, followed by a cold water quench and a hot rinse.

A SHORT CUT TO A FINISHED PRODUCT

SAVE YOURSELF TIME AND TOOL CHARGES

with Anaconda multiple-plunger press products—in a wide choice of metals

If you need parts like these in quantity, The American Brass Company can save you time and money. Through its specialized experience—and thousands of stock tools—it may save tool charges, too.

Ferrules, grommets, eyelets, deep-drawn cups and shells, and thousands of other intricate, close-tolerance parts made from strip metal are everyday business. American Brass Company design engineers and toolmakers have earned an enviable reputation for cutting costs and performing the almost impossible in design and production.

Your choice of metal: Such fabricated products can be furnished in copper, brass, bronze, nickel silver, nickel, iron, steel, stainless steel, and aluminum – in a wide variety of finishes.

Standard products: For a selection of more than 1000 eyelets of common sizes and styles, as well as eyelets kept in stock for immediate shipment, write for Catalog BG-1.

Special products: Just send a sample, drawing, or description, together with the quantity you need, the metal to be used, and other pertinent information. Address: The American Brass Company, Waterbury Brass Goods Division, Waterbury 20, Conn.

ANACONDA
MULTIPLE-PLUNGER PRESS PRODUCTS

No acid is required but, while in the bath, the work to be cleaned is subjected to an electrolytic current supplied by a d.c. generator.
For further information circle No. 310 on literature request card, page 48-B.

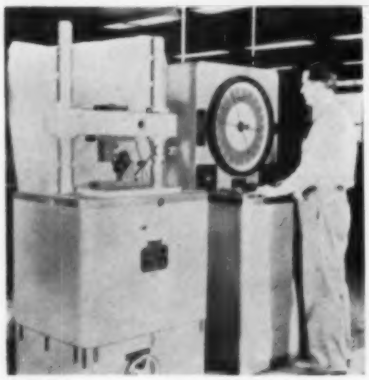
Endothermic Generator

A laboratory-size endothermic generator has been announced by Ipsen Industries, Inc. This electrically heated generator is designed for the

small scale heat treatments usually required in the laboratory or tool room heat treat department. Rated output is approximately 150 c.f.h. of endothermic atmosphere gas.
For further information circle No. 311 on literature request card, page 48-B.

Testing Machine

Baldwin-Lima-Hamilton Corp. has announced the introduction of an all-electric testing machine which automatically cycles tension and compression loads. Loading is measured and controlled by Baldwin SR-4 load cells which are based on the electrical principle of the SR-4 bonded resistance wire strain gage. Strain cycles are controlled by limit switches on platen movement. These switches reverse the direction of the electric motor drive of the machine, the actual movement being read on a dial indicator in thousandths of an inch. Strain readings are taken at 250 and 500-lb. loads during the fourth cycle.



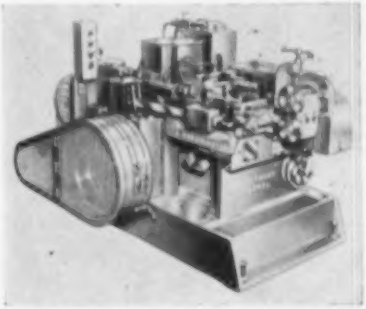
Load measurements are made on the lowest of four scales (0 to 1000 lb.) which has 2-lb. graduations on a 66-in. scale.
For further information circle No. 312 on literature request card, page 48-B.

Ovens

A new line of four junior sized utility ovens for small batch drying, curing, baking, processing, heat treating, product control and sample testing have been announced by New England Oven and Furnace Co. The models have approximately 2 by 2 by 2 ft. oven interior dimensions, but vary in temperature ranges from 100 to 1000° C. A true forced air recirculating system is maintained within the oven chamber through use of a fan and controlled intake and exhaust vents. A shielded heating element prevents radiant over-heating and aids in a more even temperature control throughout the chamber.
For further information circle No. 313 on literature request card, page 48-B.

Cold Heading

A new solid die, double stroke cold heading machine with production rates ranging from 300 to 450 screw or rivet blanks per minute has been announced by the Waterbury Farrel Foundry & Machine Co. Features of the new machine include horizontal



shifting punches, toggle actuated gate mounted on rods, friction roll feed, individually adjustable punch holders, cam operated shifter and cut-off, magnetic brake, sturdy cut-off and transfer lever, all shafts mounted in roller bearings, centralized lubrication system and variable speed drive.
For further information circle No. 314 on literature request card, page 48-B.

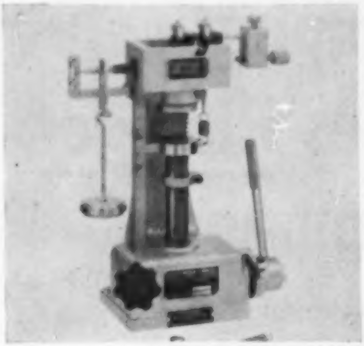
Protective Coating

A new vinyl plastic protective coating that can be sprayed or brushed on paint spray booths has been announced by Klem Chemicals. It can be

peeled off removing paint deposit with it and leaving the booth clean. Zip Kote can be applied to other equipment.
For further information circle No. 315 on literature request card, page 48-B.

Spring Tester

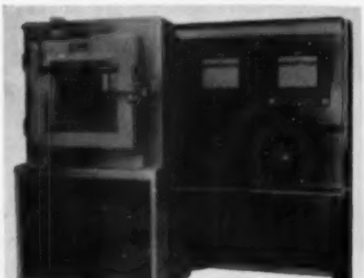
A tester for both general purpose and high quantity production testing of small compression and extension springs for loads and deflections has



been announced by Carlson Co. The capacity of the tester is ⅛ oz. to 25 lb. for spring lengths to 5 in. and diameters to 1¾ in., with a guaranteed accuracy of 0.25%.
For further information circle No. 316 on literature request card, page 48-B.

Instrument Console

A new console form of instrument localization, used in conjunction with environmental test equipment, has been announced by Tenney Engineering, Inc. The new console is a unit-



in-itself with all switches, dials, and contacts mounted on the front for easy control and more accurate operation. It can be placed at a distance for any operation which involves danger.
For further information circle No. 317 on literature request card, page 48-B.

Coating for Aluminum

A conversion coating for aluminum and zinc designed to meet specification MIL C-5541 has been announced by Oakite Products. The new product

10 to 100% faster pumping— with Stokes Ring-Jet diffusion pumps

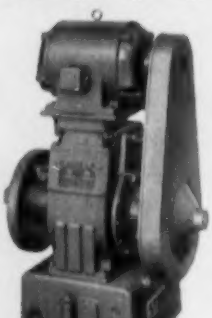
Major advance in diffusion pump design increases capacities, shortens vacuum pumping cycles, permits operation against higher forepressures.

A COMPLETELY DIFFERENT design concept makes it possible for Stokes Ring-Jet diffusion and booster pumps to provide high vacuum pumping performance never before possible. Instead of a single jet cone, these pumps have a ring of jets. This construction increases cross-sectional area of the air path . . . retains short distance to the condensing surface.

The result: for a given size of pump, the Ring-Jet design increases pumping capacity from 10% to more than 100%. Pumping speeds are substantially higher in the critical ranges. A 6-inch Stokes Ring-Jet booster can evacuate 760 cfm at 50 microns, 1400 cfm at 15 microns. The pump can also operate against higher forepressures. At normal heat input, the 6-inch booster is rated at 2.4 mm.; the 16-inch diffusion pump, 0.35 mm.

This increased efficiency cuts pumping cycles, permits use of smaller mechanical roughing pumps. It puts added value into many types of vacuum processing equipment . . . such as metallizers, vacuum furnaces and exhausting systems. Both diffusion and booster pumps are available in a range of sizes from 4 to 16 inches. For specifications, or for a consultation on your high vacuum application, call your nearest Stokes office. F. J. Stokes Machine Company, *Vacuum Pump Division*, 5508 Tabor Road, Philadelphia 20, Pa.

MICROVAC mechanical pumps for high capacity, low maintenance



Ideal for use as roughing pumps, or as sole sources of vacuum in applications not requiring diffusion pump performance. New design features assure fast pumping, high capacity, efficiency over wide pressure range. Trouble-free operation is provided by fail-safe design, intake screen filters, double-spring exhaust valves. Write for Catalog 751 for complete information.

STOKES

on this 1941 model the stainless steel trim is

still bright and handsome!

after 15 years of continual use and exposure

The photographs of the car are unretouched

yes- Stainless Steel

serves best on any automobile!

Fifteen long years . . . but only a good start in life for ever-bright *stainless steel*—the beautiful metal that outlasts the car! • Today's automotive stylists specify stainless for its *service-proved* strength and corrosion-proof brilliance, and a substantial portion of the industry's orders for stainless calls for coils of SUPERIOR Stainless Strip Steel—precision made, uniform in every desired composition, temper and finish.

Superior Steel
CORPORATION
CARNEGIE, PENNSYLVANIA

is said to impart resistance against corrosion and to improve paint adherence. The coating becomes integral with the treated metal surface. If the surface should be damaged, it confines corrosion within the area of the exposed metal—corrosion does not creep under the undamaged paint to cause blistering. It may be applied in either tank or washing machine.
For further information circle No. 318 on literature request card, page 48-B.

Conveyors

Cooney Industries, Inc., has announced a new heavy-duty conveyor. It will handle hot forgings, heavy awkward-shaped objects and parts with slick surfaces. It comes equipped

with casters and handles placed on each side so it may be rolled from job to job or it may be used in stationary locations. Wire mesh belt is available in a variety of weaves and with any spacing and size of flight.
For further information circle No. 319 on literature request card, page 48-B.

Quench Tank

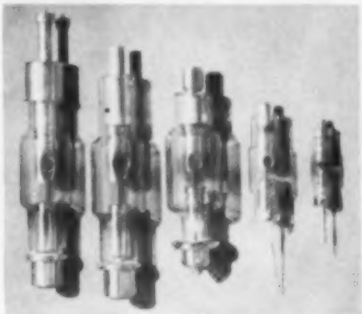
A new air-operated quench tank has been announced by Waltz Furnace Co. This unit is hot dipped galvanized and consists of one tank within the

other. The space between the two tanks is used as an overflow space for water on the quench tank and for storage and cooling on the oil tank. A pump is provided on the oil tank for circulating the oil. The pump

takes the oil from the outer tank and pumps it into the bottom of the inner tank forcing the oil over the top of the inner tank and back to the cooling section. Tanks do not require pit settings or any other special installation.
For further information circle No. 320 on literature request card, page 48-B.

X-Ray Tubes

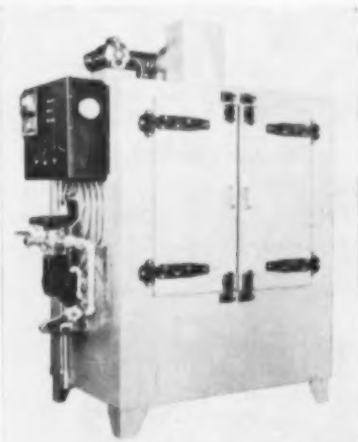
Machlett Laboratories, Inc., has announced five new industrial X-ray tubes, the PR series for use in the



120 to 260 PKV range. They are designed especially for lightweight, self-contained, portable X-ray tube heads (either oil or pressurized gas insulated).
For further information circle No. 321 on literature request card, page 48-B.

Portable Oven

The Carl Mayer Corp. has announced a new portable oven with a recirculating heating system and positive automatic temperature controls. Six models are in production. Tem-



perature ranges are from 500 to 1000° F.; oven sizes range from 20 x 20 x 20 in. to 26 x 38 x 50 in. Safety controls are standard equipment on all models. Ovens use either gas or electricity.
For further information circle No. 322 on literature request card, page 48-B.

HOUGHTON Liquid Salt Baths

It costs you nothing to put him ON YOUR HEAT TREATING TEAM

When you use Houghton Liquid Salt Baths, the Houghton Man goes to work for you—on your job, in your plant. It is up to him to see that you get the results you want. And you'll get them, for Houghton's skilled technicians are backed up by many years of experience and the most extensive research facilities in the business.

Houghton salts also offer many other advantages. *They are versatile*—covering a temperature range of 350°F. to 2400°F. to meet every type of heat treating requirement. They give *fast heating.* Since thermal conductivity from salt to metal is exceptionally high, Houghton Salts bring your parts up to heat faster than is possible with other methods. They give *precise temperatures,* controlled within two or three degrees. Houghton's doubly-refined salts assure you the exacting results you planned for.

Houghton's research facilities and on-the-job service go with every Houghton salt you buy. Put them to work now. Just talk to your Houghton Man or write directly to E. F. Houghton & Co., 303 W. Lehigh Ave., Philadelphia 33, Pa.

LIQUID SALT BATHS . . . *products of*

E. F. HOUGHTON & CO.
PHILADELPHIA · CHICAGO · DETROIT · SAN FRANCISCO

Ready to give you on-the-job service . . .

APPLICATION and EQUIPMENT new literature

326. Abrasives
18-page catalog 556 on various types of shot and grit abrasives. SAE specifications and types of cleaning and peening methods.*Cleveland Metal Abrasive*

327. Adhesive Bonding
New 8-page booklet on application techniques and precautions, advantages and limitations of adhesive bonding at room temperature. *Rubber & Asbestos*

328. Alloy Castings
Bulletin 3150-G on castings for heat, corrosion, abrasion resistance. *Duraloy*

329. Alloy Chart
Comparison of AISI, SAE, ACI, AMS, WAD and PWA chromium and chromium-nickel stainless specifications. *Cannon-Muskegon*

330. Alloy Steel
68-page "Aircraft Steels" includes revised military specifications. Also stock list. *Ryerson*

331. Alloy Steel
32-page book on abrasion resisting steel. Properties, fabricating characteristics, uses. *U.S. Steel*

332. Alloy Steel
Data book on the selection of the proper alloy steel grades for each manufacturer's needs. *Wheelock, Lovejoy*

333. Aluminized Wire
6-page booklet on aluminized steel wire and its applications. *American Chain & Cable*

334. Aluminum
12-page booklet on extruded shapes, tube and pipe, coiled sheet, forgings and properties of aluminum alloys. *Revere*

335. Aluminum Alloy
Bulletin 103 on high strength aluminum alloy which ages at room temperature. *Federated Metals Div.*

336. Aluminum Die Castings
Bulletin on design and manufacture of aluminum die castings. *Hoover Co.*

337. Aluminum Extrusions
Data on commercial aluminum extrusions. *Superior Industries*

338. Ammonia for Heat Treat
Booklets on "Applications of Dissociated Ammonia", "Ammonia Installations for Metal Treating", "The Nitriding Process", "Carbonitriding". *Armour*

339. Atmosphere Furnace
Information on mechanized batch-type atmosphere furnaces for gas cyaniding, gas carburizing, clean hardening or carbon restoration. *Dow Furnace*

340. Atmosphere Furnace
Bulletin on controlled atmosphere furnace. *Industrial Heating Equipment*

341. Atmosphere Furnace
12-page bulletin 1054 on electric furnaces with atmosphere control for hardening high speed steel. *Sentry*

342. Automatic Control
40-page catalog No. 4A shows design and various models of contact metal relays. *Assembly Products*

343. Barrel Finishing
Folder on methods and materials. Problems and requirements. *Oakite*

344. Batch-Type Furnaces
Bulletin SC-174 on furnaces in the operating range of 1400 to 1750° F. for various heat treating processes. Suction radiant tube fired units and mechanized systems. *Surface Combustion*

345. Bearings
20 data sheets give special properties and case histories for new Rulon oil-free bearing material. *Dixon Corp.*

346. Bearings
Chart on chemical, mechanical and work characteristics of sintered bronze or iron bearing materials. *Bound Brook Oil-Less Bearing*

347. Beryllium Copper
12-page booklet on casting alloys. Properties of alloys and castings. How Be-Cu castings are made. *Beryllium Corp.*

348. Beryllium Copper
4-page data sheet features a section detailing the specific methods for heat-treating beryllium copper. Engineering specifications including physical properties and the effect of these properties on heat treatment. *American Silver Co.*

349. Bimetal Applications
New 44-page booklet, "Successful Applications of Thermostatic Bimetal", contains uses, formulas, calculations. *W. M. Chace*

350. Black Oxide Coatings
8-page booklet on black oxide coatings for steel, stainless steel and copper alloys. *Du-Lite*

351. Blast Cleaning
Folder describes advantages of installing a meter on blast cleaning equipment. *Hickman, Williams & Co.*

352. Blast Cleaning
12-page brochure describes and illustrates various features of super tumblast machine. Specifications. *Wheelabrator*

353. Blast Cleaning
Complete information on Malleabrasive for cleaning and finishing. *Globe Steel Abrasive*

354. Bolts
16-page booklet on high-strength bolting for structural joints includes ASTM specifications covering this bolting material. *Bethlehem Steel*

355. Burnishing
Bulletin B-10 on new series of compounds aids in selection of proper compound. *Apothecaries Hall*

356. Calibrating Machine
Bulletin 115 on calibrating system for accurate measurement of mechanical forces. *Morehouse Machine*

357. Carbides
84-page catalog of sintered carbides, hot pressed carbides, cutting tools, drawing dies, wear resistant parts. *Metal Carbides*

358. Carbides
4-page bulletin on general-purpose heavy-duty sintered carbide. *Firth Sterling, Inc.*

359. Carbon
New technical bulletin gives chemical and physical characteristics of metallurgical carbons. *Barnebey-Cheney*

360. Carbon and Graphite
20-page catalog on carbon and graphite applications in metallurgical, electrical, chemical, process fields. *National Carbon*

325. Investment Casting
Design data developed over a period of more than 10 years in producing investment castings are outlined in this new 40-page booklet. Typical physical, mechanical and chemical properties of the 26 alloys most suitable to Haynes' investment-

casting method are included. When to consider the investment-casting process to solve design, production and metallurgical problems is considered. The booklet also includes case histories of some of the parts produced in quantity by the method. *Haynes Stellite Co.*

361. Carbon Steel Castings
Data folders on four types of carbon steel castings. Composition, properties, hardenability bands, uses. *Unitcast*

362. Carbon Steel Tubing
Card 142A on properties of seamless and welded carbon steel pressure tubing. Fabricating operations performed on such tubing. *Babcock & Wilcox*

363. Carburizing
Data folder on Aerocarb E and W water-soluble compounds for liquid carburizing. Case depth vs time curves. Per cent carbon and nitrogen penetration curves. *American Cyanamid*

364. Carburizing Salts
Folder on salts for liquid carburizing. *Swift Industrial Chemical*

365. Centrifugal Castings
Three bulletins give metallurgical specifications for ferrous and nonferrous

cold
heading
profits
start
here

The quality of the cold heading wire you use is the beginning of higher cold heading profits.

That's why so many users specify J&L Cold Heading Wire to help them get the highest quality finished parts at increased production rates, and lowest manufacturing costs.

J&L Cold Heading Wire will meet your exact requirements for:

Precise Chemical Grade and Physical Characteristics
Surface Qualities
Finish
Uniformity

The result—when you specify J&L, you assure the best heading performance. Investigate the profit-making possibilities of J&L Cold Heading Wire today. It's tops in quality—competitive in price.

Jones & Laughlin
STEEL CORPORATION · PITTSBURGH

J·L
STEEL

castings, applications and variety of castings. *Sandusky Foundry & Machine*

366. Chromate Finishing
File on chromate conversion coatings for prevention of corrosion and paint-base treatment of nonferrous metals. *Allied Research Products*

367. Cleaners
Folder on immersion, electrolytic, spray cleaners, phosphate coaters, strippers, drawing compounds, additive agents. *Northwest Chemical*

368. Cleaning
Folder on di-phase cleaning gives equipment, construction features, spray and blow-off features, heating systems. *Solventol*

369. Cleaning Compound
Bulletin B-6 on water displacing compound for producing unspotted, dry surfaces. *Apothecaries Hall*

370. Cobalt Alloy
12-page booklet, "Haynes Alloy No. 25", tells of the unique properties of this cobalt-base alloy. *Haynes Stellite*

371. Coil Handling
New 28-page booklet on coil stock handling and punch press feeding equipment. *F. J. Littell Machine Co.*

372. Coil Tester
Bulletin No. 109 on instrument for detecting shorted turns in multi-turn coils. *Rubicon*

373. Cold Rolled Steels
32-page booklet on stainless, alloy and carbon spring steels, and other specialties. Melting, temper, finishes. *Crucible Steel*

374. Continuous Processing
New 6-page Bulletin 561 on equipment for continuous processing lines; punch and shear lines, including coil cars, pay-off and coiling reels, levelers, press feeds, stitchers, slitters, bridles, shears and accessory equipment. *Herr Equipment Corp.*

375. Controller
Bulletin 4-11 on electric proportional controllers for dew point, pressure, temperature in batch process, combustion atmosphere and heat treating furnaces. *Foxboro*

376. Copper Alloys
64-page book on free-cutting brass, copper and bronze. *Chase Brass*

377. Copper Alloys
40-page book on eleven copper alloys. Properties, cleaning, annealing. *Seymour*

378. Creep Testing
Data on operation and instrumentation of Arcweld lever arm creep testing machine. *Minneapolis-Honeywell*

379. Creep Testing
Bulletin RR-13-54 on new creep testing machine. *Riehle*

380. Creep Testing
Bulletin 4208 on five types of creep testing machines for standard sized metal specimens. *Baldwin-Lima-Hamilton*

381. Cut-Off Wheels
Folder gives data, operating suggestions and grade recommendations of cut-off wheels. *Manhattan Rubber Div.*

382. Cutting Fluids
New 16-page booklet on cutting and grinding with wax cutting fluids. Advantages of wax coolants. *S. C. Johnson*

383. Cutting Oil
Facts on more efficient and economical plant operation through use of right lubricants described in "Metal Cutting Fluids" booklet. *Cities Service*

384. Degreasing
New bulletin on OPNT vapor degreaser describes and diagrams its construction. *Circo Equipment*

385. Demineralization
24-page article on demineralizing considers development, trends and applications of multi-bed and mixed-bed ion exchange. *Graver Water Conditioning*

386. Descaling
New 16-page brochure, 608, on equipment for continuous, mechanical descaling by shot blasting. *Pangborn*

387. Descaling Stainless Steel
Bulletin 25 on descaling stainless steel and other metals in molten salt. *Hooker Electrochemical*

388. Dew Point Control
Bulletin No. 21-C on instrument which indicates, records and controls dew point automatically. *Ipsen*

389. Die Steel
Folder and stock list on Olympic FM air hardening, high carbon-high chomium die steel with sulphide additives for improved machinability. *Latrobe Steel Co.*

390. Drawing Titanium
6-page reprint on drawing and other forming methods, including severe forming operations. *Brooks and Perkins*

391. Dryers
New 52-page Bulletin D-100 on dryers for air, gas and liquids for low dew points. *C. M. Kemp Mfg. Co.*

392. Electric Furnaces
Bulletin on electric heat treating furnaces gives summary of progress in furnace developments. *Holcroft*

393. Electric Furnaces
Folder on electric furnaces with zone control, temperature indication, automatic control. *L & L Mfg. Co.*

394. Electric Furnaces
Brochure on electric heat treating, melting, metallurgical tube, research and sintering furnaces. *Pereny Equipment*

395. Electric Furnaces
36-page brochure on electric arc furnaces for steel melting. Various designs and special features for production and pilot sizes. *Swindell-Dressler*

396. Electrodes
New 16-page catalog on spectroscopic electrodes and powders. How purity is secured and maintained. *National Carbon*

397. Electron Microscope
20-page brochure describes in detail ten case histories in which the electron microscope has been at work solving problems of development and control in industrial laboratories. *RCA*

398. Extrusion
Folder describes the hot extrusion process and gives its history. *Jones & Laughlin*

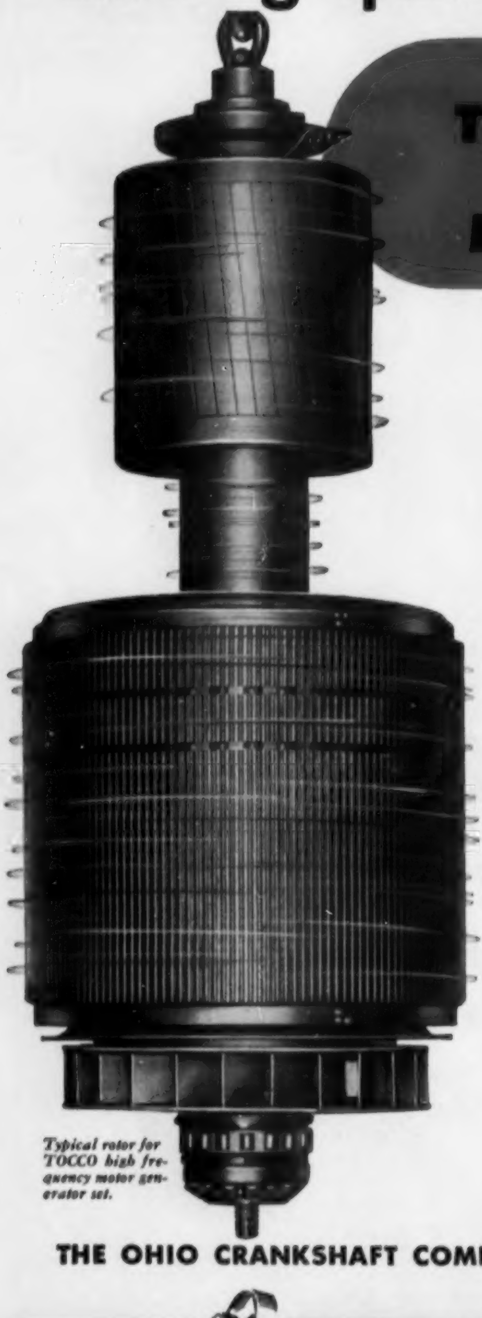
399. Extrusions
New 20-page booklet on extruded rod and bar stock in beryllium copper, beryllium aluminum and beryllium nickel alloys, beryllium metal and oxide. *Beryllium Corp.*

400. Ferro-Alloys and Metals
100-page book gives data on more than 250 different alloys and metals produced by the company. *Electro Metallurgical*

401. Filters
32-page booklet on filters, mixers, pumps and tanks for liquid processing. *Alsop Engineering*

"Nothing Spins Like a Top"... *except*

TOCCO's VERTICAL Hi-Frequency Motor-Generator Sets



Typical rotor for TOCCO high frequency motor generator set.

First with Vertical MG Sets—TOCCO

In 1943 TOCCO designed and built the first vertical motor-generator sets for furnishing hi-frequency power for induction heating applications. Now with thirteen years of continuous production experience, we are far and away the world's largest supplier of these units.

Advantages of TOCCO Vertical MG Sets

The large TOCCO vertical type motor generator set has numerous advantages over conventional horizontal type sets. Vertical construction permits the use of very large bearings and also minimizes the hazard of major damage to the set in the unlikely event of a bearing failure. Longer bearing life is achieved due to lower pressure and uniform loading of the bearings. Maintenance is greatly simplified because the rotor can be removed vertically with a simple hoist. Anti-vibration mountings between the base and the MG rotor-stator assembly practically eliminate vibration. No special foundations are needed. Lastly, TOCCO's vertical design cuts necessary floor space to less than one-half the area required by horizontal motor-generator sets.

TOCCO Vertical MG sets are available in sizes up to 350 KW and frequencies from 1000 to 10,000 c.p.s.

Only Time-Tested Vertical MG Sets—TOCCO

There are over a thousand TOCCO vertical MG sets in actual service TODAY—more than all competitive horizontal makes combined. Write us for descriptive bulletin giving full details on the advantages and construction details of TOCCO Vertical MG Sets.

THE OHIO CRANKSHAFT COMPANY

TOCCO

JUST PUSH A BUTTON

NEW FREE BULLETIN — *Mail Coupon Today*

THE OHIO CRANKSHAFT CO.
Dept. R-8, Cleveland 5, Ohio

Please send copy of "TOCCO High Frequency Motor-Generator Sets."

Name__________
Position__________
Company__________
Address__________
City_____ Zone____ State____

402. Finishing
Catalog A-654 gives complete story on planning industrial finishing systems and shows many installations of cleaning and pickling machines. *R. C. Mahon*

403. Flaw Location
New 4-page pamphlet discusses all aspects of flaw location with dye penetrants from precleaning to interpreting results. *Turco Products*

404. Flow Meter
New 6-page Bulletin 301 on Transometer and how it is used for flow, ratio and combustion control, for multiple fuel totalization and for interchangeable control in fuel switch over. Liquids it will handle. *Askania Regulator*

405. Flow Meter
Bulletin P22-6 on pneumatic square root extracting flow transmitter gives ranges, dimensions, diagrams. *Bailey Meter*

406. Flow Meters
Bulletin 201 on flow meter for gas used in heat treating. *Waukee Eng'g.*

407. Forgings
New 12-page booklet on aluminum, brass and copper forgings. Parts forged and their advantages. Properties of alloys used. *Revere Copper & Brass*

408. Forgings
94-page book on die blocks and heavy-duty forgings. 20 pages of tables. *A. Finkl & Sons*

409. Forgings
New bulletin on forge steel making, open die forging, machining, heat treating and finishing. *National Forge*

410. Forgings
Folder on large forgings of carbon and alloy steel. *Struthers Wells Corp., Titusville Forge Div.*

411. Forgings
16-page bulletin on production of seamless forged and rolled rings. Chart on how to calculate ring weights. *Alco Products*

412. Formed Shapes
26-page catalog No. 1555 contains drawings and dimensions of more than 100 shapes. *Roll Formed Products Co.*

413. Furnace Accessories
8-page catalog on auxiliary items used with foundry melting furnaces. *Lindberg-Fisher Div., Lindberg Engineering Co.*

414. Furnace Belts
44-page catalog describes metal belts for quenching, tempering, carburizing and other applications. *Ashworth Bros.*

415. Furnace Fixtures
Bulletin 111 on cast Ni-Cr fixtures for gas carburizing. *Fahralloy*

416. Furnace Fixtures
16-page catalog on baskets, trays, fixtures and carburizing boxes for heat treating. 66 designs. *Stanwood Corp.*

417. Furnaces
6-page folder on gas-fired, oil-fired and electric furnaces. Typical installations. *Electric Furnace*

418. Furnaces
32-page catalog of industrial equipment includes furnaces and furnace accessories, special valves, mechanical equipment, materials handling equipment. *Salem-Brosius*

419. Furnaces
Bulletin on electric heat treating furnaces describes five series and accessories. *Lucifer Furnaces*

420. Furnaces
Series of bulletins on controlled atmosphere, carburizing, nitriding, hardening furnaces. *American Gas Furnace*

421. Furnaces
Brochures on pot furnaces, nitriding, austempering, and martempering and salt baths. *A. F. Holden*

422. Furnaces
16-page Bulletin 135 on industrial furnaces and atmosphere generators. Continuous systems. *Continental Industrial Engineers*

423. Gages
Folder on design and construction of reversible plug gages. *Pratt & Whitney*

424. Gamma Radiography
16-page bulletin describes isotopes used, equipment and applications. *Budd Co.*

425. Gas Analysis
Data sheet on instruments used to record gas and vapor concentrations during combustible gas analysis. *Minneapolis-Honeywell*

426. Gas Carburizing
8-page booklet on furnace equipment for gas carburizing. Continuous and batch processes. *Surface Combustion*

427. Gas Generator
Bulletin 753R on endothermic generator gives construction, principles of operation, special features. *Hevi-Duty*

428. Globar Furnaces
Bulletin 153 describes nine types of furnace using silicon carbide heating elements for temperatures to 2800° F. *Hevi-Duty*

429. Gold Plating
Folder on salts for bright gold plating. Equipment needed. *Sel-Rex*

430. Graphitic Tool Steel
48-page booklet on heat treating data, properties and 46 specific applications of graphitic tool steel. *Timken*

431. Hardness Conversion
Chart comparing various testing systems and tensile strength of carbon and alloy steels. *Babcock & Wilcox Co.*

432. Hardness Tester
Data on hardness testing scleroscope with equivalent Brinell and Rockwell C numbers. *Shore Instrument*

433. Hardness Tester
New bulletin on Wolpert-Gries Micro-Reflex hardness tester for loads from 10 to 3000 g. *Gries Industries, Inc.*

434. Hardness Tester
Bulletin on Impressor portable hardness tester for aluminum, aluminum alloys and soft metals. *Barber-Colman*

435. Hardness Testers
Catalog of testers for normal hardness, superficial testing, accessory and special testing and micro and macro hardness testing. *Wilson Mechanical Instrument*

436. Hardness Testers
20-page book on hardness testing by Rockwell method. *Clark Instrument*

437. Hardness Testing
8-page catalog B-953 on principles and standards of Brinell hardness testing, and types of machines. *Steel City Testing Machines*

438. Heat Treating Ammonia
24-page "Guide for Use of Anhydrous Ammonia" describes heat treating and other metallurgical uses. *Nitrogen Div.*

439. Heat Treating Fixtures
24-page catalog on heat and corrosion-

Testing a section of steel trailer on a 60,000 lb. Baldwin BTE. Photo courtesy of Trailmobile, Inc.

get more for your money with a Baldwin BTE universal testing machine

This versatile machine stands ready to serve you in *two* ways. Ruggedly built, and virtually maintenance-free, it is ideal for heavy-duty production testing in your shop. Yet it is so accurate and reliable that it is ideal for high precision testing in your laboratory.

Five features that make the moderately-priced Baldwin BTE universal your best buy:

- Loading system is completely isolated from weighing system. Friction errors are eliminated.
- True null-balance system provides accuracy well within 0.5% of true load or 0.1% of load range.
- 24″ multi-range masked dial indicator is illuminated by fluorescent light for easy reading.
- Range can be changed during test.
- Stress cycling equipment, stress strain recorder, extensometer, load pacer and other accessories are available.

Baldwin BTE universals are built in capacities from 10,000 to 5,000,000 lbs. For full information, get your copy of illustrated bulletin 4401. Write Dept. 1624, Electronics & Instrumentation Division, BLH Corporation, Waltham, Massachusetts.

BALDWIN BLH LIMA-HAMILTON

ELECTRONICS & INSTRUMENTATION DIVISION

BALDWIN-LIMA-HAMILTON

DIVISIONS: Austin-Western • Eddystone • Hamilton • Lima • Electronics & Instrumentation • Loewy-Hydropress • Madsen • Pelton • Standard Steel Works

resistant equipment for heat treating and chemical processing. 30 classifications of equipment. *Pressed Steel*

440. Heat Treating Fixtures
24-page catalog B-8 on muffles, retorts, baskets, other fixtures for heat treating in gas or salt baths. *Rolock*

441. Heat Treating Fixtures
12-page bulletin on wire mesh baskets for heat treating and plating. *Wiretex*

442. Heat Treating Furnaces
32-page catalog on high-speed gas furnaces for heat treating carbon and alloy steels; also pot furnaces for salt and lead hardening. *Charles A. Hones*

443. Heating Elements
24-page booklet on elements for electric furnaces and kilns includes technical data, uses, physical and electrical specifications. *Norton*

444. High Speed Steel
Folder on Electrite Double Six M-2 XL tungsten-molybdenum high speed steel containing alloy sulphides for improved machinability and increased tool life. *Latrobe Steel Co.*

445. High-Strength Steel
48-page book on T-1 steel, its properties and applications. *U.S. Steel*

446. High-Temperature Belts
Bulletin T-241 on belts of high-temperature alloy for heat treat furnaces. *Electro-Alloys*

447. High-Tensile Steel
Bulletin on nickel-copper steel of low-alloy, high-strength type. *Youngstown Sheet and Tube*

448. High-Vacuum Furnaces
12-page brochure No. 790 on vacuum furnaces for melting and casting titanium, zirconium, germanium, copper, iron and steel. Also furnaces for annealing, hardening, brazing. *F. J. Stokes*

449. Induction Hardening
Bulletin M-1938 on induction hardening machine gives advantages and application of system. *Cincinnati Milling Machine*

450. Induction Heating
New 36-page bulletin on high-frequency induction heating unit for brazing, hardening, soldering, annealing, melting and bombarding. *Lepel*

451. Induction Heating
60-page catalog tells of reduced costs and increased speed of production on hardening, brazing, annealing, forging or melting jobs. *Ohio Crankshaft*

452. Induction Heating
12-page bulletin B-6519 on motor generator sets, r.f. generators, work stations, handling equipment. *Westinghouse Electric*

453. Induction Heating Control
2-page data sheet on detector and controller and how it is used for continuous, batch and selective induction heating processes. *Leeds & Northrup*

454. Industrial Furnaces
Complete information on all types of custom built furnaces. *Martin Mfg. Co.*

455. Instruments
34-page book describes 37 instruments for electrical, physical, resistance-welding, ultrasonic and other measurements. *Brush Electronics*

456. Insulation
40-page industrial products catalog on insulations, refractory products and others. *Johns-Manville*

457. Investment Casting
New bulletin on gas fired furnaces for investment casting. Also includes chart of characteristics of typical investment casting alloys. *Surface Combustion*

458. Laboratory Mill
4-page reprint on rolling mill for laboratory studies, which may be operated as a 2-high, 3-high or 4-high mill. *Fenn Mfg.*

459. Lubricant
8-page folder describes use of molybdenum disulfide lubricant in cold forming, cold heading and other applications. Case histories. *Alpha Corp.*

460. Lubricants
Fifth revision of 4-page booklet on dispersions for industry lists 41 colloidal and semi-colloidal dispersions for the metal working industries. *Acheson Colloids*

461. Lubricants
Bulletin 103A lists and describes 17 types of molybdenum disulfide lubricants. *Alpha Molykote*

462. Machining Alloy Steels
24-page bulletin on economical combination of microstructure, tool form, cutting speed and feed for each machining operation. *International Nickel*

463. Magnesium
42-page booklet on wrought forms of magnesium. Includes 31 tables. *White Metal Rolling & Stamping*

464. Magnesium Specs
Bulletin DM12n on specifications of government agencies, AMS, SAE, ASTM. *Dow Chemical*

Here at Fahralloy we don't have any sidelines. All we do is one thing—make heat and corrosion resisting castings. But we figure that's a full time business in itself. You see, we look at each and every job as something special. We want to be sure it is properly engineered for the service conditions to which it will be exposed. Because of this thorough approach, we've been able to render a service to FAHRALLOY customers far beyond the mere making of a casting . . . one that can be measured in many instances in dollars and cents saved! You'll be pleased with the extra special service that goes with every heat resisting casting that bears the name FAHRALLOY.

Won't you let us serve you soon?

THE FAHRALLOY CO.

150th & Lexington Ave. — Harvey, Illinois

In Canada — Fahralloy Canada, Ltd., Orillia, Ontario

465. Melting Furnace
Bulletin gives specifications, diagrams, performance and other technical data on Simplex melting furnaces. *Lindberg Engineering*

466. Melting Furnaces
28-page catalog on Heroult electric melting furnaces. Types, sizes, capacities, ratings. *American Bridge*

467. Metal Cutting
8-page booklet on friction, abrasive, cut-off and long cut saws. *Ty-Sa-Man Machine*

468. Metallograph
20-page booklet, E-232, on Balphot all-purpose metallograph—bright field, dark field, polarized light, phase contrast. *Bausch & Lomb*

469. Microhardness Tester
Bulletin describes the Kentron microhardness tester. *Torsion Balance Co.*

470. Microscopes
Catalog on metallograph and several models of microscopes. *United Scientific*

471. Moisture Measurement
12-page bulletin on how to measure water vapor in air and other gases. Gravometric, dew point and wet and dry bulb methods, and others. *Pittsburgh Lectrodryer*

472. Molybdenum
72-page book gives data on unalloyed molybdenum and four arc-cast alloys. Several pages of references. *Climax Molybdenum*

473. Molybdenum
New folder on pallet method of shipping molybdenum. *Molybdenum Corp.*

474. Nondestructive Testing
8-page bulletin on equipment for nondestructive testing of bars, rods, tubing. *Magnetic Analysis*

475. Nondestructive Testing
Data on new nondestructive thickness tester. *Unit Process Assemblies*

476. Nonferrous Wire
Folder gives wire gage and footage chart and data on beryllium copper, phosphor bronze, nickel, silver, brass and aluminum wire. *Little Falls Alloys*

477. Oil Quenching
8-page brochure tells in detail how carbon steel often can replace alloy steel when additive is used in the quenching oil. *Aldridge Industrial Oils*

478. Openhearths
Brochure on modern openhearth design and construction. *Loftus*

479. Ovens
Bulletin 10S on cabinet ovens describes those for use with gas, electric and steam heat for temperatures to 600° F. *Young Brothers*

480. Ovens
New 16-page catalog on techniques used in process heating systems. Methods combining radiation and convection. *Jensen Specialties*

481. Ovens
16-page bulletin No. 53 on various types of core and mold ovens, special ovens and heat treating furnaces. *Carl-Mayer*

482. Pickling Baskets
12-page bulletin on mechanical picklers, crates, baskets, chain and accessories. *Youngstown Welding & Eng'g*

483. Pickling Baskets
Data on baskets for degreasing, pickling, anodizing and plating. *Jelliff*

484. Plating
Data sheet 5.1-4 on temperature control
(*Continued on page 48-A*)

THAT one is no good!

Wouldn't you like to be *that* sure about duds in your own production? Nondestructive radiography (either x-ray or gamma ray) could do it for you maybe.

***Anything* you buy or sell which needs "seeing into" is fair game for this versatile inspection method . . . weldments, castings, assemblies, plastics, wood, metal . . . right across the board from paper-thin stuff to foot-thick steel.**

If you need to spot hidden defects to keep a firm finger on quality control, we'll be glad to tell you what radiography can do for you.*

** There's probably a Picker District office near you (see local 'phone book). Or write Picker X-Ray Corporation, 25 South Broadway, White Plains, New York.*

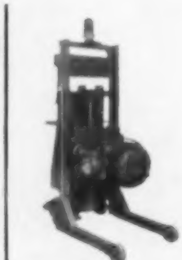
5 to 50 KV
Small as a filing cabinet, yet it will x-ray anything up to 1/8'' thick aluminum. Self-contained, completely rayproof.

150 KV
Penetrates up to 1'' steel and 5½'' aluminum (more with screens). Stationary or mobile for "on-the-spot" x-raying.

250 KV *portable*
Rugged, lightweight 250 KV tubehead with separate remote power chassis. Will enter openings as small as 15'' square.

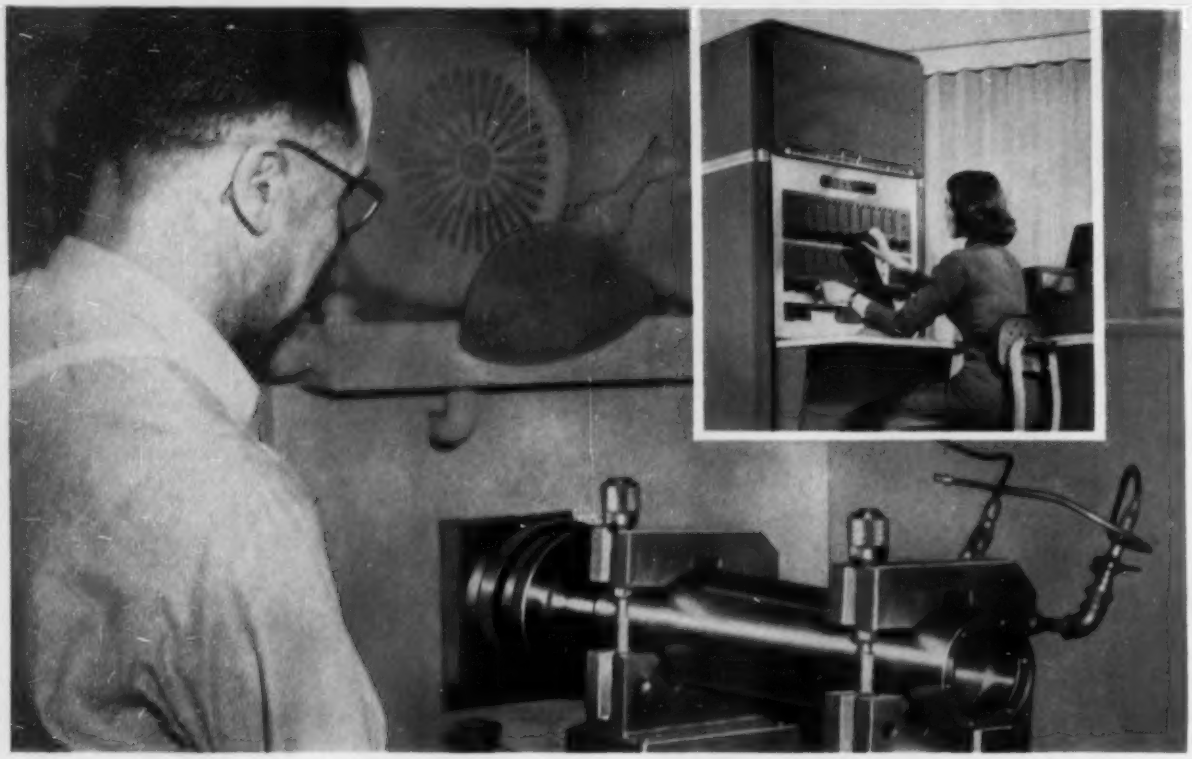
RADIOGRAPHIC CABINETS
Rayproof enclosures obviate need for lead-lined rooms. Available with or without feeder tables.

260 KV *crane or dolly*
For heavy-duty inspection (up to 3'' steel). Operating down to 60 KV, will x-ray a wide range of other materials.



GAMMA *Sources, equipment, containers.*
Panoramic, circumferential, and directional projectors using cesium, iridium or cobalt isotopes.

one source for everything in Picker x-ray **radiography and fluoroscopy**



ELECTRONIC COMPUTER
Gets An Assist From B&W Mechanical Tubing

A remarkable "think" machine—called the Type 650 IBM Magnetic Drum Data Processing Machine—is designed to serve the large areas of computation not now covered by the huge "brains" or the smaller electronic calculators. A product of International Business Machines Corp., this commercial and engineering computor can "think", "remember" and store information, and is capable of simultaneous computation and calculation.

As its name implies, a vital part of this unique machine is the rotor shell of the Magnetic Drum which provides the information storage space on the drum. To produce this shell with its required magnetic property, high quality B&W Mechanical Tubing is cut to size, turned, ground, copper-plated, then coated with a nickel-cobalt special magnetic-field plating and finally dynamically balanced.

In a precision machine such as this, the selection of B&W Mechanical Tubing depended upon its ability to meet not only specific fabrication requirements but also a number of unusual service conditions. For example, the drum rotor turns at high speed and must retain its stability. In addition, temperatures and vibrations can also directly affect its function in the machine.

The highly satisfactory performance of B&W Mechanical Tubing in this uncommon application is typical of its performance in *all* types of products and services with *all* kinds of requirements. Write for Bulletin 361 for the comprehensive story of how B&W Mechanical Tubing serves Industry. The Babcock & Wilcox Company, Tubular Products Division, Beaver Falls, Pa.

TA-6005 (M)

B&W
TUBULAR PRODUCTS DIVISION

Seamless and welded tubular products, seamless welding fittings and flanges—in carbon, alloy and stainless steels

(Continued from page 45)

of plating tanks describes electric and pneumatic temperature control, recording, indicating and non-indicating instruments. *Minneapolis-Honeywell*

485. Plating Solutions
Operating manuals for plating with metal fluoborate solutions. *Baker & Adamson.* See page 149.

486. Polishing Materials
20-page booklet includes samples of emery, aluminum oxide and silicon carbide papers and 12 polishing cloths. *Buehler, Ltd.*

487. Potentiometers
12-page bulletin 270 on several different potentiometers including portable models. *Rubicon*

488. Powder Cutting
New 4-page folder lists applications of powder scarfing, gouging, lancing and washing. *Hoeganaes Sponge Iron Corp.*

489. Precision Casting
18-page booklet on use of ethyl silicate describes setting and hardening, precoat and investment preparations, typical formulae, investment casting problems. *R. W. Greeff & Co.*

490. Precision Castings
12-page booklet describes process, inspection procedures, design and some brass and aluminum castings alloys. *Atlantic Casting and Engineering*

491. Precision Castings
New 5-page folder on investment casting. *Engineered Precision Casting*

492. Pure Metals
Data sheets on vacuum melted cobalt, copper, iron and nickel. *Vacuum Metals*

493. Pyrometer Indicator
New 8-page catalog 25-3 describes indicator and models in which it is available. *Thermo-Electric*

494. Pyrometers
32-page thermocouple and accessory bulletin. *West Instrument*

495. Quench Agitation
Information on mixers and agitators, including units applicable to industrial quenching equipment. *Mixing Equipment*

496. Quenching
Bulletin No. 11 on quenching oil also discusses advantages of quench agitation. *Sun Oil Co.*

497. Quenching
Bulletin 120 on use of heat exchangers to provide heat control in quenching bath. *Niagara Blower*

498. Quenching Oil
10-page book on new oils for the quenching process gives results on hot wire quench test and in plant operation. *Sinclair Refining Co.*

499. Radioactive Chemicals
24-page booklet describes radioactive chemicals and their uses. Lists those available. *Baker & Adamson*

500. Recorders
12-page bulletin contains methods of applying 6-in. strip-chart recorders for pressure, liquid level, temperature, flow, mechanical motion. *Bristol*

501. Refractories
8-page catalog of super refractory shapes, tubes, insulators for use to 3000° *F. Morganite*

502. Refractory Cement
Bulletin discusses refractories and heat-resistant concrete. *Lumnite Div.*

503. Refractory Coating
Data on aluminum oxide and silicon carbide coating which may be sprayed on. *Norton Co.*

504. Residual Stresses
32-page, pocket-size booklet on residual stresses in cold-finished steel bars and their effect on manufactured parts. *La Salle Steel*

505. Rhodium Plating
Data on properties, thicknesses required, costs, operation, applications. *Technic*

506. Rust Prevention
72-page book on cleaning, preservation, and packaging of metals. Causes of corrosion. *E. F. Houghton*

507. Rust Preventives
12-page bulletin on water-soluble rust preventive. *Production Specialties*

508. Salt Bath Furnace
Bulletin 655 on immersed electrode salt bath furnace gives advantages, applications, construction. *Hevi Duty*

509. Salt Bath Furnaces
Data on salt bath furnaces for batch and conveyorized work. *Upton*

510. Saws
Catalog C-53 describes 35 models of metalcutting saws. *Armstrong-Blum*

511. Shell Molding
6-page brochure on shell mold casting of copper-base alloys describes how it is done and applications. *Aurora Metal Co.*

512. Shell Molding
16-page booklet on resin-coated sand for shell molding discusses equipment, coating techniques and production of blown shell molds and cores. *Plastics Div., Monsanto Chemical Co.*

513. Shot and Grit
Handy calculator has size data for SAE grades of shot and grit. *Pangborn*

514. Sintered Carbides
24-page booklet on the characteristics of the various grades, for research and design engineers. *Kennametal*

515. Sodium
28-page booklet on using sodium in dispersed form tells how dispersions are prepared and handled, and their advantages. *Ethyl Corp.*

516. Specifications Index
28-page cross index lists copper alloy specifications of nine different Government agencies. *American Brass*

517. Stainless Castings
Bulletin on advantages of corrosion-resistant castings. *Ohio Steel Foundry*

518. Stainless Steel
Two booklets on 200 series of low nickel, austenitic stainless steels, give applications and properties compared with 300 series. *Republic Steel*

519. Stainless Steel
Booklet on 430 stainless. Properties, fabrication. *Sharon Steel*

520. Stainless Steel
Selector gives machinability, physical and mechanical properties, corrosion resistance of various grades of stainless steel. *Crucible Steel*

521. Stainless Steels
10-page booklet contains charts, graphs, data on cold rolled mechanical properties, elevated temperature properties, physical properties and corrosion resistance of chromium-nickel-manganese steels. *Allegheny Ludlum*

522. Stainless Strip
32-page brochure on 20 types of stainless strip steel. Recommended applications, chemical, physical and mechanical properties. *Superior Steel Corp.*

523. Stainless Tubing
8-page folder TB-410 on use of seamless and welded stainless steel pipe and stainless steel welding fittings for corrosive environments and elevated temperature applicants. *Babcock & Wilcox*

524. Stereomicroscopes
38-page catalog D-15 shows value of three-dimensional microscopes for industrial assembly lines and research laboratories. *Bausch & Lomb Optical*

FIRST CLASS
PERMIT No. 1595
(Sec. 34.9 P.L. & R.)
Cleveland, Ohio

BUSINESS REPLY CARD
No Postage Stamp Necessary If Mailed In the United States

4c POSTAGE WILL BE PAID BY—

METAL PROGRESS
7301 Euclid Avenue
CLEVELAND 3, OHIO

525. Temperature Control
8-page booklet R-22 on equipment to detect and correct thermocouple circuit failure in heating and melting operations. *Peerless Electric*

526. Temperature Control
New 8-page bulletin on temperature control systems contains selection guide, terminology, types of control systems. *Wheelco Instrument Div.*

527. Temperature Conversion
Chart converts degrees Fahrenheit to Centigrade and vice versa from —400 to 4000° and shows range of sensing elements. *Thermo Electric*

528. Tempilstiks
"Basic Guide to Ferrous Metallurgy", a plastic laminated wall chart in color. *Claud S. Gordon*

529. Test Accessories
22-page Bulletin 46 on instrumentation, tools and accessories for mechanical testing machines. *Tinius Olsen*

530. Test Specimens
Data on machine for cutting test specimens to ASTM specifications. *Sieburg Industries*

531. Textured Metal
16-page booklet on advantages and applications of textured metal. *Rigidized Metals*

532. Thermocouple Alloys
20-page booklet on chromel-alumel alloys gives sizes, temperature-millivolt equivalents, standards, applications. *Hoskins Mfg.*

533. Thermocouples
44-page catalog EN-S2 describes couples and assemblies for general application and for special plant and laboratory uses. Tabular data on accuracy and limits of couples. *Leeds & Northrup*

534. Thickness Measurement
Data sheet 10.9-1a on sheet and coating thickness measurement on a continuous basis. *Minneapolis-Honeywell*

535. Titanium Alloy
Data on ternary alloy with 3% aluminum and 5% chromium gives physical properties, forging temperatures, high temperature characteristics. *Mallory-Sharon Titanium*

536. Titanium Carbide
29-page pocket-sized book reviews methods of manufacture, properties, uses. Bibliography. *Titanium Alloy Mfg. Div.*

537. Tool Steel
Literature on Cromotung, oil hardening tool steel. Properties and applications. *Ziv Steel & Wire Co.*

538. Tool Steel
44-page stock list is indexed and includes sizes, weights, and analyses. Decimal conversion and hardness conversion tables. *Uddeholm*

539. Tool Steel
44-page book on tool steels for the nonmetallurgist explains the six basic kinds of tool steels and their heat treatment. *Crucible Steel*

540. Tool Steels
Specification Chart gives tool steel names and designations for 15 companies and the Army and Navy. *Vanadium-Alloys Steel*

541. Tool Steel Color Guide
Color guide to estimate temperatures has heat colors on one side and temper colors on the other. *Bethlehem Steel*

542. Tubing
New 8-page catalog on carbon and alloy steel tubing of mechanical, pressure, airframe and aircraft mechanical quality. *Ohio Seamless Tube*

543. Tubing
12-page catalog on cold drawn mechanical, capillary nickel and nickel alloy tubing. *J. Bishop & Co. Platinum Works*

544. Tubing
Bulletin on aluminum preassembled refrigerator tubes. *Wolverine Tube*

545. Tubing
Data Card 186, guide to specifications and applications of tubular products, fittings and flanges in various grades of steel. *Babcock & Wilcox*

546. Tungsten
20-page bulletin on manufacture, properties and uses of tungsten. Flow chart of tungsten production. *Sylvania Electric Products*

547. Ultra Strength Steel
Results of three year research and test program evaluating properties of Type 4340 steel for aircraft structures. *International Nickel*

548. Ultrasonic Cleaning
Folder on Sonogen ultrasonic generator for metal cleaning. *Branson*

549. Ultrasonic Testing
Data folder describes instruments using ultrasonics for various tests—immerscope, "B" scan and flaw recorder. *Curtiss-Wright*

550. Vacuum Metallizing
Bulletin 780 gives uses and advantages of vacuum metallizing, materials and properties of vacuum metallized coatings, the process, equipment. *Stokes*

551. Vacuum Metallizing
8-page catalog No. 551 on production and experimental-type metallizing units. *High Vacuum Equipment Corp.*

552. Vacuum Metallurgy
Information memo describes the high-vacuum technique and pumping systems. *Consolidated Vacuum Corp.*

553. Vanadium in Steel
189-page book on properties of ferrous alloys containing vanadium and their applications. *Vanadium Corp.*

554. Welding Electrode
Bulletin No. 5 on the development of an electrode for metal arc welding of wrought 35 Ni-15 Cr-1.25 Si alloy. *Rolled Alloys*

555. Welding Electrodes
84-page pocket-size booklet describes characteristics, coating, sizes of various electrodes and compares them with standard designations and other electrode brand names. *Harnischfeger*

556. Welding Equipment
12-page bulletin 156 on special and standard resistance and arc welding equipment. *Acro Welder Mfg.*

557. Welding Equipment
Catalog on Cadweld process and arc-welding accessories. *Erico Products*

558. Welding Repair
New 4-page booklet on repair of cast iron parts by welding with Ni-Rod and Ni-Rod 55. *International Nickel*

559. Welding Stainless
8-page Bulletin GET-1955 gives arc-welding practices for stainless steels. *General Electric*

560. Wire Mesh Belts
130-page manual on conveyor design, belt specifications, metallurgical data. *Cambridge Wire Cloth*

561. X-Ray
12-page bulletin on gamma radiography tells how to select the source, equipment, techniques and fundamentals of gamma radiation. *Picker X-Ray*

562. X-Ray Diffraction
Bulletin 8A-3505 on film or direct recording X-ray diffraction apparatus. *X-Ray Div., General Electric*

563. X-Ray Supplies
Bulletin on liquid X-ray developer, replenisher and fixer. *Philip A. Hunt Co.*

AUGUST, 1956

287	311	335	359	383	407	431	455	479	503	527	551
288	312	336	360	384	408	432	456	480	504	528	552
289	313	337	361	385	409	433	457	481	505	529	553
290	314	338	362	386	410	434	458	482	506	530	554
291	315	339	363	387	411	435	459	483	507	531	555
292	316	340	364	388	412	436	460	484	508	532	556
293	317	341	365	389	413	437	461	485	509	533	557
294	318	342	366	390	414	438	462	486	510	534	558
295	319	343	367	391	415	439	463	487	511	535	559
296	320	344	368	392	416	440	464	488	512	536	560
297	321	345	369	393	417	441	465	489	513	537	561
298	322	346	370	394	418	442	466	490	514	538	562
299	323	347	371	395	419	443	467	491	515	539	563
300	324	348	372	396	420	444	468	492	516	540	
301	325	349	373	397	421	445	469	493	517	541	
302	326	350	374	398	422	446	470	494	518	542	
303	327	351	375	399	423	447	471	495	519	543	
304	328	352	376	400	424	448	472	496	520	544	
305	329	353	377	401	425	449	473	497	521	545	
306	330	354	378	402	426	450	474	498	522	546	
307	331	355	379	403	427	451	475	499	523	547	
308	332	356	380	404	428	452	476	500	524	548	
309	333	357	381	405	429	453	477	501	525	549	
310	334	358	382	406	430	454	478	502	526	550	

METAL PROGRESS,

7301 Euclid Avenue, Cleveland 3, Ohio

Please have literature circled at the left sent to me.

Name ____________________

Title ____________________

Company ____________________

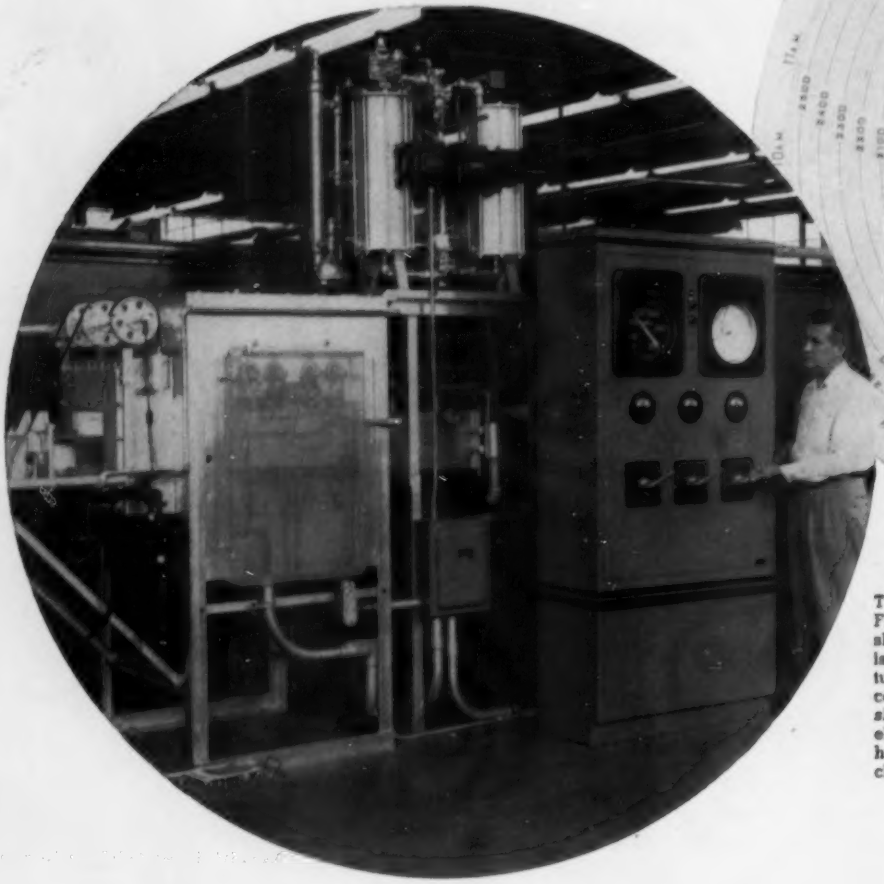
Address ____________________

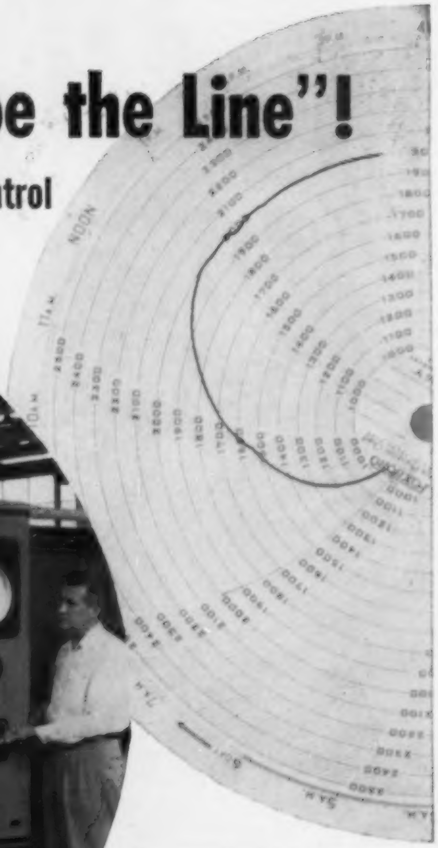
City and State ____________________

Postcards must be mailed prior to Nov. 1, 1956. Students should write direct to manufacturers.

Furnace Temperatures "Toe the Line"!

. . . under new Foxboro Electric Proportional Control





This typical chart from Foxboro M/81b Controller shows how furnace (left) is brought up to temperature and precisely held at control point *without* overshoot. Installation is on electric furnace hardening high-precision, small machined parts.

Heat treating temperatures stay right on the control line when the new Foxboro M/81b Electric Proportional Controller handles furnace heat input. This fast-acting Controller assures the furnace a "balanced diet" of B.T.U.'s despite upsets, load changes, furnace lags, or ambient temperatures.

Control action is simple — effective. The M/81b senses any tendency of temperature to move away from pre-set control point . . . automatically varies ratio of heat "time-on" to "time-off" depending on changes in furnace loading. This *Proportional-set Average-position Controller* eliminates over- and under-shoot . . . maintains unusually uniform furnace conditions.

For top performance from your electrically heated or fuel-fired muffle-type furnace . . . new or modernized . . . investigate Foxboro Electric Proportional Control. Write for Bulletin 4-11.

THE FOXBORO COMPANY, 529 NEPONSET AVENUE, FOXBORO, MASSACHUSETTS, U. S. A.

FOXBORO REG. U. S. PAT. OFF.

Electric Proportional Controllers

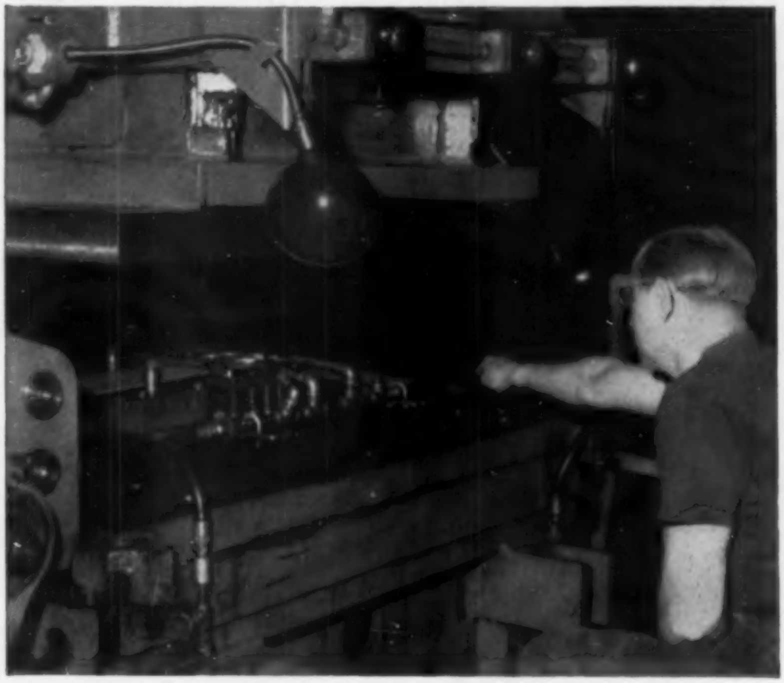
FACTORIES IN THE UNITED STATES, CANADA, AND ENGLAND

Tool Steel Topics

On the Pacific Coast Bethlehem products are sold by Bethlehem Pacific Coast Steel Corporation

BETHLEHEM STEEL COMPANY, BETHLEHEM, PA.

Export Distributor: Bethlehem Steel Export Corporation



Maker of Washers Rings the Bell with Die Made of Lehigh H

A manufacturer of steel washers found that by using a piercing die made of Lehigh H tool steel, he could get longer, more economical production runs than with dies of another grade, formerly used.

The Lehigh H die produces thousands of round washers daily, in sizes from ⅝ in. to 1 in. It is hardened to approximately Rockwell C 61, and pierces 5/32-in. C 1035 steel sheet. Because of the severity of the piercing operation, redressing of the die is required after every third turn, but only 0.020 in. is removed. Close to 100,000 washers are turned out between grinds.

Lehigh H handles this blanking job to perfection because of its outstanding wear-resistance and toughness. Lehigh H is a superb high-carbon, high-chromium grade of air-hardening tool steel. It can always be counted upon for a good job because of its resistance to wear, minimum distortion in heat-treatment, and high compressive strength.

TYPICAL ANALYSIS

Carbon 1.55	Molybdenum 0.80
Chromium 11.50	Vanadium 0.40

If there are applications in your shop which require a combination of wear- and shock-resistance, plus high compressive strength, look into the advantages of Lehigh H. Your local Bethlehem tool steel distributor, as friendly a man as you'll find anywhere, is at your service.

FILM "TEAMWORK" WINS AWARD AT COLUMBUS FESTIVAL

"Teamwork," our new 30-minute color film on tool steel, received an award for excellence in the Business and Industry category at the recent Fourth Annual Columbus Film Festival.

"Teamwork" takes you behind the scenes in describing typical applications of our carbon, oil- and air-hardening, shock-resisting, hot-work and high-speed tool steels. It is now available for showings to die-makers, heat-treaters, machinists, machine-tool manufacturers and distributors. It's also an excellent film for technical society meetings, and for student groups.

It's easy to arrange to see "Teamwork." All you need do is drop a line to the nearest Bethlehem office, or to Publications Department, Bethlehem Steel Company, Bethlehem, Pa. If possible, please select a showing date well in advance, to allow time for scheduling and shipping.

BETHLEHEM TOOL STEEL ENGINEER SAYS:

Punched Holes Often Close-in

In precision punching it is common practice to make the punch diameter exactly the same as that of the desired hole. (All the clearance required is then applied to the I.D. of the die.) For many operations involving holes greater than 1 in. diameter, for example, and stock less than ⅛ in. thick, this procedure is correct. But in other operations it is incorrect, because the elasticity of the stock causes the holes to close-in after punching, so that the holes are actually smaller than the punch which made them.

With large-diameter holes and thin stock, the elastic springback which tends to close-in a punched hole causes the stock to buckle instead, so that the hole diameter will be accurate under these conditions. On holes 1 in. in diameter and smaller, expect a close-in of 0.002 to 0.003 in. with stock ⅛ in. to ¼ in. thick, and a closing of 0.001 in. on stock 0.030 in. thick (22 gage). Closing will be negligible on stock 0.010 in. thick (32 gage) or less. For precision punching, therefore, add the expected close-in to the punch size to produce the correct hole diameter.

SPECIAL REPORTS ON FINISHING NON-FERROUS METALS

NUMBER III—Lustrous, Corrosion-Resistant Finishing with Chemical Polishing Iridite

WHAT IS IRIDITE?

Briefly, Iridite is the tradename for a specialized line of chromate conversion finishes. They are generally applied by dip, some by brush or spray, at or near room temperature, with automatic equipment or manual finishing facilities. During application, a chemical reaction occurs that produces a thin (.00002" max.) gel-like, complex chromate film of a non-porous nature on the surface of the metal. This film is an integral part of the metal itself, thus cannot flake, chip or peel. No special equipment, exhaust systems or specially trained personnel are required.

Chromate conversion coatings are widely accepted throughout industry as an economical means of providing corrosion protection, a good base for paint and decorative finishes for non-ferrous metals. Certain of these coatings also possess chemical polishing abilities that have luster-producing, as well as corrosion-inhibiting, effects on zinc and cadmium plate, zinc die castings and copper alloys. However, continued developments in this field have been so rapid that many manufacturers may not be completely aware of the breadth of application of this type of finish. Hence, this discussion of the many ways in which this chemical polishing characteristic can be used in final finishing or pre-plating treatments to produce a lustrous appearance with distinct display and sales appeal and appreciable savings in cost. Report I on decorative, corrosion-resistant finishes and Report II on paint base corrosion-resistant finishes are available on request.

The degree of luster possible on a surface is a function of the degree to which the surface can be smoothed. Leveling to provide a smooth surface can be achieved by mechanical or chemical means, or a combination of these, depending upon the luster desired and the original condition of the metal. Chemical polishing effectively imparts luster otherwise difficult and costly to obtain. For this reason, it is often used to supplement or entirely replace mechanical polishing, depending upon the application and the original condition of the metal. Chemical polishing has the additional advantage of providing overall treatment of the submerged part. It reaches into even the deepest corners and recesses that are otherwise inaccessible. Certain of the Iridites are specifically designed to perform this chemical polishing operation. Also, they provide corrosion protection as do all Iridites, thus may be used as a final finish or a pre-plating polish.

If Iridite is to be used as a final finish, in contrast to pre-plating treatment, the chromate conversion coating generated is allowed to remain, providing good corrosion resistance. Color inherent in these Iridite films ranges from a yellow cast to yellow iridescent. These coatings may be used without further treatment where this color is acceptable and good corrosion resistance is desired. Further, these basic coatings can be tinted by dyeing. Among the dye tints available are shades of red, yellow, blue and green. If desirable, the basic coatings can also be modified by a bleach dip leaving a clear bright or blue iridescent finish. In all cases bleaching reduces corrosion resistance.

As examples of this type of final finishing, Iridites #4-73 and #4-75 (Cast-Zinc-Brite) make possible for the first time, lustrous chemical polishing of the as-cast surface of zinc die castings. Thus, in many cases, sizeable savings in finishing cost are realized by elimination of plating costs. This economical method can be used on tools, appliance parts, toy pistols, locks and many other small castings. Another example is the treatment of copper and brass parts, such as welding tips, to eliminate buffing and provide additional corrosion resistance. In many cases, handling costs are reduced appreciably by replacing piece-part handling with bulk processing. Still another example of the use of this chemical polishing and protective quality of Iridite is a simple system of zinc plate, Iridite and clear lacquer instead of more costly electroplated finishes. Typical of this type of lustrous finish are builders hardware and wire goods.

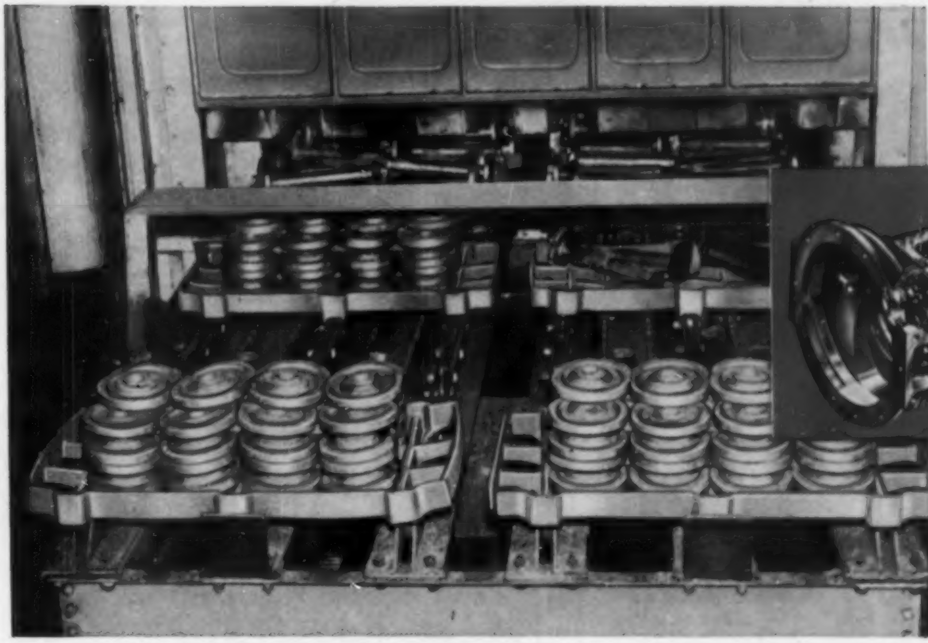
As a pre-plating treatment, in contrast to final finishes, Iridite can be used to chemically polish zinc die castings or copper prior to plating. In such cases, Iridite should be applied as an in-process step, so that the protective film is removed before the plating cycle. The savings in handling, material and labor costs are obvious. This process has made it practical to plate chrome directly over copper on steel, conserving nickel, yet producing a lustrous chrome finish. Used after stripping faulty plate in reprocessing zinc die castings, Iridite restores luster to the casting, thus making possible replating without blistering.

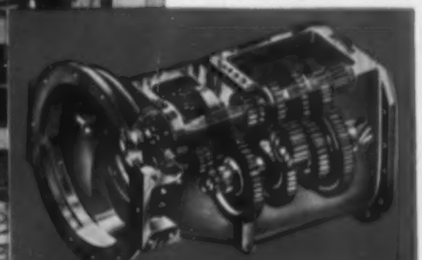
Other Iridite finishes are available to produce maximum corrosion resistance, a wide variety of decorative finishes and excellent bases for paint on all commercial forms of the more commonly used non-ferrous metals. As a final finish, appearance ranges from clear bright to olive drab and brown and many films can be bleached or dyed. As a paint base Iridite provides excellent initial and retentive paint adhesion and a self-healing property which protects bare metal if exposed by scratching. Iridites have low electrical resistance. Some can be soldered and welded. The Iridite film itself does not affect the dimensional stability of close tolerance parts.

Iridites are widely approved under both Armed Services and industrial specifications because of their top performance, low cost and savings of materials and equipment.

You can see then, that with the many factors to be considered, selection of the Iridite best suited to your product demands the services of a specialist. That's why Allied maintains a staff of competent Field Engineers—to help you select the Iridite to make your installation most efficient in improving the quality of your product. You'll find your Allied Field Engineer listed under "Plating Supplies" in your classified telephone book. Or, write direct and tell us your problem. Complete literature and data, as well as sample part processing, is available. Allied Research Products, Inc., 4004-06 East Monument Street, Baltimore 5, Maryland.

"DRIVER-HARRIS TRAYS give a far lower heat-hour cost than any others we have used"...says Minneapolis-Moline





Minneapolis-Moline's new "Ampli-Torc" drive mechanism as used on their 445 tractor, which Minneapolis-Moline describes as "new from radiator to drawbar."

In heat-treating gears for the "Ampli-Torc" drive, these trays give an average life of *3000 hours* of intermittent heating to *1700° F.* and quenching.

Minneapolis-Moline's "Ampli-Torc" drive mechanism on their new M-M 445 tractor enables the operator to choose two forward speeds in each gear setting *without* stopping, clutching, shifting gears, or changing throttle. This allows a wide range of 10 forward and 2 reverse speeds.

The gears for the "Ampli-Torc" demand fine steel—and heat-treating with special care. The gears must be uniformly exposed on all surfaces. These and all other gears made by this highly regarded manufacturer are heat-treated in trays of a Driver-Harris Alloy, expertly designed to their requirements by Driver-Harris.

When it comes to heat-treating fixtures, trays, pots, retorts or muffles, you gain two distinct "bests" by ordering from Driver-Harris. You gain the benefit of our 38 years of experience in supplying the alloys which keep your heat-hour costs *down* to the absolute minimum—*plus* Driver-Harris engineering know-how in designing furnace fixtures that exactly fit *your* needs. Specify D-H alloys, as do Minneapolis-Moline and many other leaders of American industry, and both these benefits can be yours.

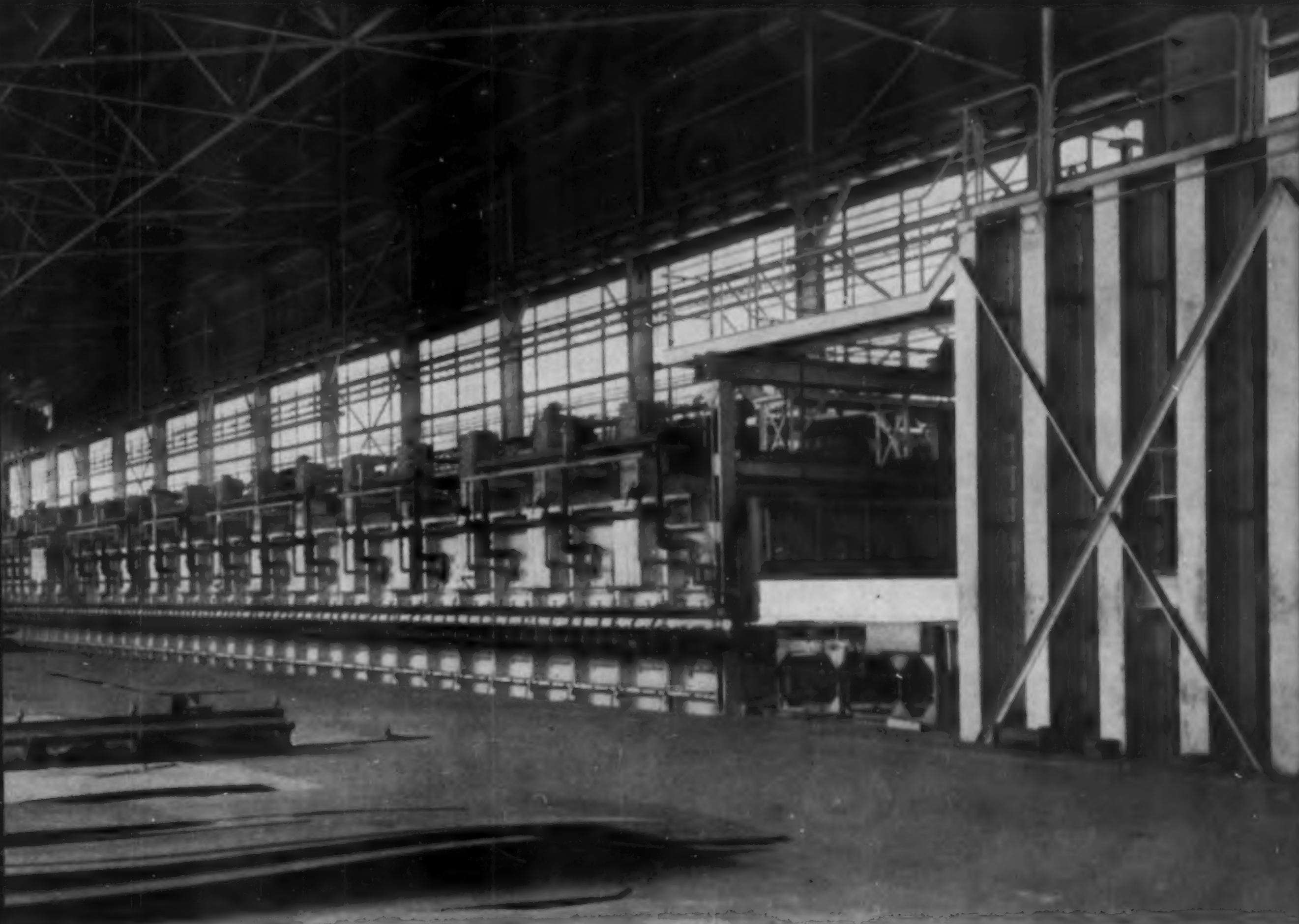
*T.M. Reg. U. S. Pat. Off.

Specify Nichrome*, Chromax*, Cimet*, made only by

Driver-Harris COMPANY HARRISON, NEW JERSEY

BRANCHES: Chicago, Detroit, Cleveland, Louisville, Los Angeles, San Francisco • In Canada: The B. GREENING WIRE COMPANY, Ltd., Hamilton, Ontario

MAKERS OF THE MOST COMPLETE LINE OF ELECTRIC HEATING, RESISTANCE, AND ELECTRONIC ALLOYS IN THE WORLD



limits in Lukens' new 202' furnace

STAINLESS steel plate up to 130 inches wide, 1 inch thick and 40 feet long is heat treated in a new line now operating at Lukens Steel Company, Coatesville, Pa. Designed by the Drever Co., Philadelphia, the line—longer than a football field—handles austenitic stainless alloy plates.

To handle the work that Lukens produces, the furnace was designed for accurate, flexible temperature control. 90 Bloom burners, firing either natural gas or No. 2 oil, supply heat under control of a battery of *ElectroniK* instruments. Through their *Air-O-Line* pneumatic control systems, these instruments regulate heat input to each furnace zone. They hold temperatures at the values set by the operator . . . throughout working ranges between 900 and 2000°F.

Close temperature control of this big furnace is the result of good furnace design . . . and top performance by instrumentation. It's the kind of job for which *ElectroniK* controllers have been chosen in thousands of metalworking and metal producing plants for more than a decade. Whether you're planning new equipment or modernizing, be sure that you select *ElectroniK* instrumentation . . . to be sure of the best in controls, made by the world's largest manufacturer of controls.

Let's talk over your specific control problems. Just call your local Honeywell field engineer . . . he's as near as your phone.

MINNEAPOLIS-HONEYWELL REGULATOR CO., *Industrial Division*, Wayne and Windrim Avenues, Philadelphia 44, Pa.—in Canada, Toronto 17, Ontario.

● **REFERENCE DATA: Write for Catalog 1531, "*ElectroniK* Controllers" and for Price List 56-1, "Furnace and Oven Controls."**

MINNEAPOLIS
Honeywell
BROWN INSTRUMENTS
First in Controls


For modern living... the style is Stainless!
A rich, lustrous and, above all, serviceable metal that denotes quality at its finest . . . that's Sharon Stainless Steel.
Nothing looks so well so long as stainless steel, but, more important, modern living standards demand a metal that will resist denting, corrosion, road abrasion and pitting. Stainless is beauty all the way through. It's not a softy with a thin skin.
This maximum utility plus excellence of finish and consistent uniformity, coil after coil, have been big reasons why Sharon has remained a leading supplier of stainless steel to the automotive industry since the very beginning.
SHARON Stainless Steel
SHARON STEEL CORPORATION Sharon, Pennsylvania
DISTRICT SALES OFFICES: Chicago, Cincinnati, Cleveland, Dayton, Detroit, Grand Rapids, Indianapolis, Los Angeles, Milwaukee, New York, Philadelphia, Rochester, San Francisco, Sharon, Seattle, Montreal, Que., Toronto, Ont.

Rochester, San Francisco, Sharon, Seattle, Montreal, Que., Toronto, Ont.

"INCREASED TAP LIFE FROM 250 TO 4000 PIECES"

Cities Service Chillo Cutting Oil produces astounding results for C.S.S. Machine & Tool Company, Philadelphia, Pa.

Metal stamping . . . precision grinding . . . machining . . . stud welding . . . tool and die making. These are some of the expert operations performed by the 120 skilled employees of C.S.S. Machine & Tool Company of Philadelphia . . . operations based on many years' knowhow and teamwork. And for the past year, with Cities Service cutting fluids, this work has been done with even greater precision, greater efficiency than ever before.

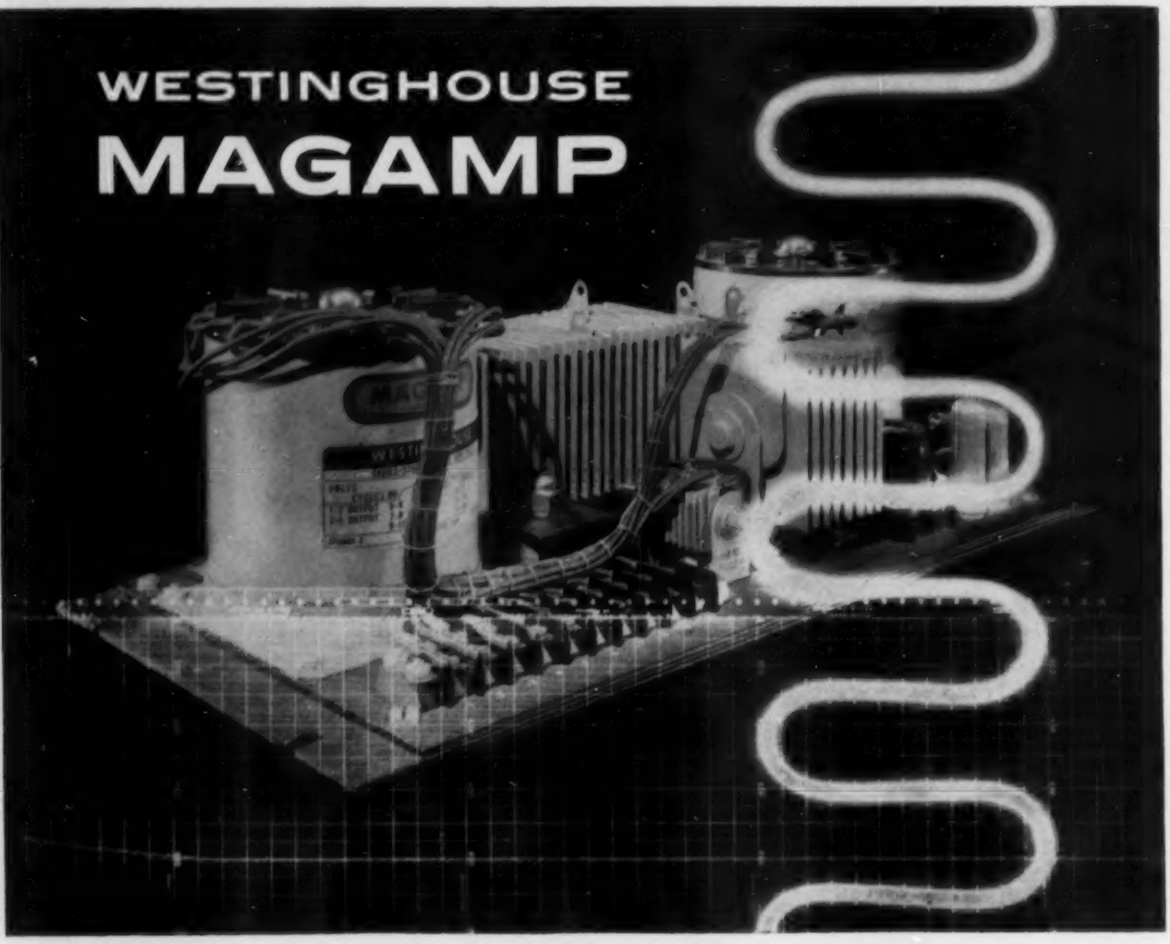
In its tapping operation, for example, C.S.S. increased tap life from an average 250 pieces to over 4000 pieces with Cities Service Chillo Cutting Oil. And in a drilling operation with its Brown and Sharpe Automatics, time required to make one piece was cut from 240 to 165 seconds!

Says President F. G. Schutz: "Cities Service Chillo Cutting Oils are the best we've ever seen. Likewise, Cities Service Lubrication Engineers. It's wonderful to deal with someone who knows our operation so well and has products that help improve it."

If you have a lubrication problem, or even if you're running smoothly, talk with a Cities Service Lubrication Engineer. He's known for solving problems, known for making smooth operations still smoother. Or, if you prefer, write: Cities Service Oil Company, Sixty Wall Tower, New York 5, N. Y.

CITIES SERVICE

QUALITY PETROLEUM PRODUCTS



Links temperature control with ten times longer life

With Westinghouse Magamp* magnetic amplifiers you can assure extraordinary predictable life for the critical job of amplifying temperature control signals; plus the fact that Magamp controls bring significant dollar savings.

Actually, these link units are rated for at least 20 years of stable, trouble-free service. They are unaffected by heat, dirt or corrosive atmospheres and have no moving parts to stick or jam. In standard panel assemblies, you can apply Magamps for control on industrial furnaces regardless of size.

In most cases, Magamp link units offer first cost savings of up to 50% over conventional controls. You'll see lower lifetime costs, too, since Magamp eliminates replacement and maintenance expense of conventional electronic controls.

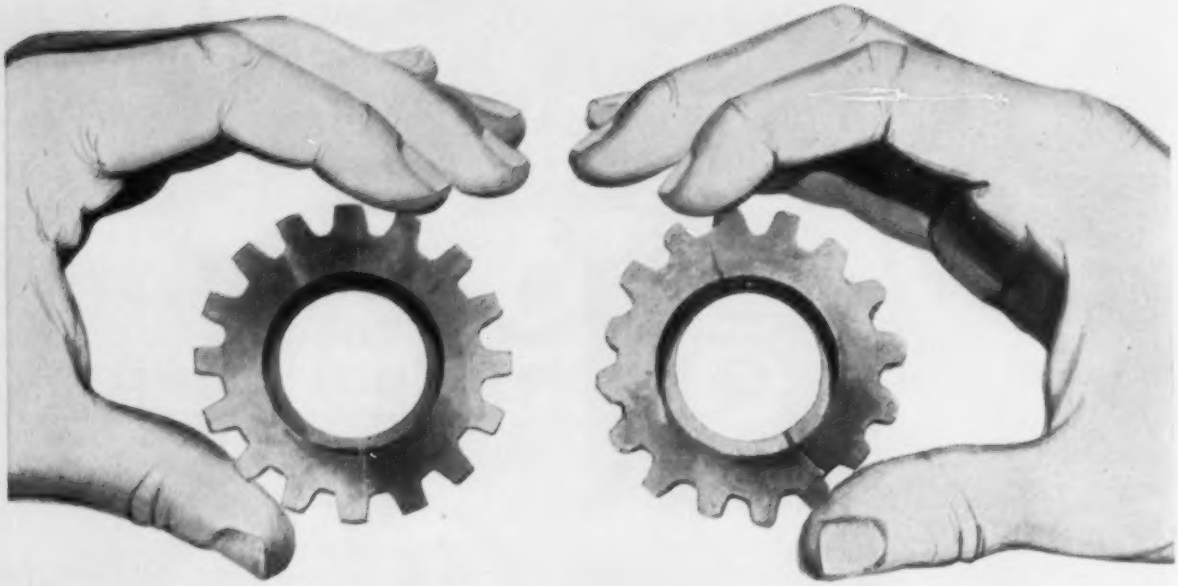
Further facts, ratings, and application data for standard Magamp link units are yours in a free Facts Folder. Contact your local Westinghouse sales engineer, or write: Westinghouse Electric Corporation, 3 Gateway Center, P. O. Box 868, Pittsburgh 30, Pennsylvania.

*Trade-Mark

J-01006

WATCH WESTINGHOUSE!

*WHERE **BIG** THINGS ARE HAPPENING **TODAY!***



Metal Progress

Volume 70, No. 2 August 1956

Critical Points . . .

BY THE EDITOR . . .

Research Into Metals – by Producers and Consumers

Early summertime seemed to be the time for the Editor to visit research laboratories, either to review acquaintances with older ones or to attend coming-out parties for the new ones. The first such visit illustrated vividly the rapid growth of sponsored research in the United States. Compared with the situation in 1935, when he first dropped in at Battelle Memorial Institute in Columbus, Ohio, there has been a five-fold increase in laboratory floor space, a 20-fold increase in staff and an 80-fold increase in dollar volume of sponsored research—a perfect example of increasing returns, and a tribute to the quality of work being done and to the astute management. Battelle's most recent additions are on a 400-acre tract some 15 miles from the present address, where three buildings for the study of power reactors and components are nearing completion, at a cost of a cool half million each. (Modern research is expensive!) The above figures on growth do not include, by the way, Battelle's laboratories at Geneva and Frankfurt, established not so much to use foreign brains to work for American clients as to study difficult problems for European industrial firms.

Compared with the work-a-day appearance of these quarters in Columbus, the new General Motors Technical Center, west of Detroit, at Warren, Mich., glitters like an architect's dream – as indeed it should, being the creation of Eero Saarinen, one of the best of them now living. It does little good to say that this group of 25 buildings, owned by America's largest consumer of metals, occupies 330 acres of ground and employs nearly 5000 scientists, engineers, technicians and executives, and is rumored to cost 125 million. It is more truly an assemblage of activities – some considerably enlarged – which previously have been scattered over GM Land. Kettering, the grand old man of automotive research, likened it to a golf course where an intelligent player can make practice shots. "If

Aerial View of General Motors Technical Center at Warren, Mich.

he's good, eventually he will break 70!" he said. Most interesting is the subdivision of activities into four separate units – engineering, manufacturing, styling and research – each heading up to its own vice-president and coordinated only by a general staff reporting directly to the president of the Corporation. This, you might say, would involve some duplication of equipment and effort. For example, each of these units has its own metallurgical department, staffed and equipped appropriately to its duties, and they work in complete independence. However, a major problem has many aspects; the men in the Engineering Unit would be occupied with phases much closer to production than those angles that are tackled by the Research Unit. Any of the units, when it develops a new idea attractive to one of the car divisions, an accessory division, an engine or appliance division, tries to sell – literally *sell* – it to that manufacturing group.

United States Steel Corp., the world's largest producer of steel, has also recently collected a number of scattered laboratories into some new buildings at Monroeville, due east of Pittsburgh, at the Pennsylvania turnpike. The airplane view shows laboratories for applied research in the group of buildings at the right. Most interesting to this observer was the strip mill where automatic controls and inspection devices are studied and improved, and the continuous electroplating unit – pint-sized in comparison – which has been responsible for the enormous mills now making tin plate and galvanized. The laboratory for fundamental research is at the left of the view; its equipment and staff have been moved from the quarters at Kearny, N.J. Fittingly enough it is named the Edgar C. Bain Laboratory for Fundamental Research, and the ornamentation over the portal shows a space model of alpha iron, a flame, and upsoaring wings, which I interpret to mean that this is the place where iron and heat and imaginative inquiry are joined. In industrial activities, "fundamental" and "applied" research merge into one another; at Monroeville a rough-and-ready distinction is that if an answer to a question is needed within a limited time – say, six months – it is "applied" research; a longer inquiry goes "fundamental".

Then, on another day, to Westinghouse's new research center nearby, and to its admirable metals plant 30 miles further east at Blairsville. At the first-mentioned much is made of theoretical work, to judge from the plush offices occupied by the thinkers. For a minute I imagined I was approaching the quarters of the Corporation's president! But no – merely the abode of pure science. Here I was told of one example wherein a group of mechanical engineers, metallurgists, experts in magnetism and in corrosion, working together, solved a difficult problem with much profit. It appears that turbines are sold to a specified efficiency, and the maker gets a

Aerial View of U.S. Steel Research Center at Monroeville, Pa.

sizable bonus for each extra percentage point in actual performance. So the commercial department says to the research laboratory, "If we can increase the inlet steam temperature by 50° F., the efficiency will go up 0.6%, and this is worth about $300,000 extra on a 300,000-kw. machine." The mechanical engineers said the most critical item was the first row of buckets on the turbine wheel. Their temperature resistance could readily be boosted if the conventional high-chromium martensitic steel were replaced with a chromium-nickel alloy, but the proposed material has poor damping characteristics – dangerous harmonic vibrations would be set up under operating conditions. Here's where the magnetic boys came in: They said that, generally speaking, nonmagnetic alloys have poor damping, whereas ferromagnetic alloys have good. So it was necessary to make the first row of a cobalt-base alloy. The result is an austenitic, ferromagnetic alloy which dampened out the harmonics, but it turned out to have poor corrosion resistance. Then the corrosion expert suggested a pinch of silicon to induce the proper amount of passivity. . . . This bit of teamwork – largely based on theoretical concepts – could pay for the entire research laboratory's expense that year!

Westinghouse's pilot metal manufacturing research plant at Blairsville is equipped to do almost anything – and close to a commercial scale for specialties. For only one example: Semi-commercial production of small horseshoe magnets for electric meters by the shell molding and by the investment process was under way to discover the competitive advantages and the modifications desirable to improve the product and lower the cost, whereupon the operation could be transferred bodily to the meter factory. Another important example is the vacuum melting and casting of 2000-lb. ingots in special molds in such a way as to reproduce the macrostructure of the large ones from which rotor forgings are made. Such ingots made and forged from electrolytic iron and refined carbon will help supply a reference datum to which can be related the specific effect of several variables which in combination are responsible for some recent turbo-generator failures – none of which, by the way, happened to machines that were built by Westinghouse.

Westinghouse Research Laboratories of Pittsburgh

World's Largest Forging Die for a 50,000-Ton Press

So large the plaster model was made in two
pieces to keep within dimensional tolerances.
To sink this half-die required two months of continuous work,
day and night. Aluminum forgings to be made
in it are for a 4-jet seaplane; they are 13 ft.
long, 3 ft. wide, 12 in. thick, and weigh 3000 lb.
Photo courtesy Aluminum Co. of America

Tool Life Increased With New Steel

*By J. Y. RIEDEL**

A new chromium-molybdenum toolsteel has been developed with improved shock resistance and service life in both hot and cold work applications. (TS)

THE COMBINATION of hot and cold shock resistance and high hardness for resistance to wear in a single tool is one of the most difficult yet most desirable characteristics sought by users. A toolsteel with such properties would be versatile and could be used for a wide variety of tools ranging from rivet sets and chisels to hot headers and die-casting dies.

Such a combination seems to have been realized in a new steel, called Bearcat, recently developed by Bethlehem Steel Co. Its nominal composition is 0.50% C, 0.70% Mn, 0.27% Si, 3.25% Cr and 1.40% Mo. Heat treatment is relatively easy and when fully annealed, machinability is about 95% of that of a 1% carbon steel.

One of the applications in which it has given remarkable service is the notching die used to make automobile windshield garnish mold from 0.020-in. cold rolled strip. The production rate is 330 pieces per hour on a 28-ton press. Two other grades of steel have been used in this application, a manganese-chromium-tungsten oil hardening steel and a chromium-tungsten shock resisting steel. A maximum of 1400 pieces was produced before the tool broke. Because of the severity of the application this was considered good production, even though it was necessary to change the die about five times a day, or 25 times a week.

When the new toolsteel was adopted, up to 10,000 pieces per die were produced so that dies lasted the full week without replacement. Considering the amount of downtime saved, as well as the cost of approximately $50 to make a die, the change-over was an improvement of major importance.

Similar savings were realized in the fabrication of the plate used as the cutting edge on highway snowplows. Fifteen holes, 11/16 in. square, must be punched in the ½-in. thick, 0.80% carbon steel plate. Four different grades of silicon-manganese shock resisting steels had been used by the snowplow manufacturer and the service life of the punches varied from 300 to 1500 holes per punch. Punches made from the Bearcat toolsteel, hardened to C-56 to 57, produce an average of 5500 holes. Only a light dressing is required after punching about 1500 holes.

Shear blades used to cut steel reinforcing bars and joists were formerly made from silicon-manganese steel, and in one plant about 400 tons of material was sheared with each side of the

*Toolsteel Engineer, Bethlehem Steel Co., Bethlehem, Pa.

Die Set Used for Notching Windshield Garnish Molding

blade before redressing was required. When the new toolsteel, hardened to C-59, was tried average production rose to more than 830 tons of material per side.

A hot work application in which the new alloy has been used successfully is the hot riveting of boilers. With standard rivet sets made from water hardening carbon steel, no more than 300 hot rivets could be driven before the sets cracked or spalled. Occasionally it was possible to extend the life of the sets by recupping, but more often this did not prove successful. With the new rivet sets, the average run increased from 300 to nearly 2500 before recupping was required. Furthermore, this steel lends itself very well to the recupping operation, which is done by grinding and requires no subsequent heat treatment. It also retains its original hardness under heat, regardless of the length of exposure.

In forging, the steel should be preheated at 1200 to 1300° F. before it is raised to forging temperature, 2000 to 2050° F. Forging should be discontinued at 1700° F. and the piece should be reheated if necessary. The forging should be cooled slowly by burying in lime, silocel, ashes or other insulating material. Normalizing is not recommended.

Annealing should be carried out in sealed containers filled with an inert material. After heating to 1500 to 1550° F. the steel is held at temperature for 1½ hr. for each inch of thickness. For the best machining properties it is cooled slowly to 1000° F. and then air cooled.

The work must be hardened either in a pro-

Punching holes in Plate Used for Snowplow Edges

Shear Used to Cut Reinforcing Bars

tective atmosphere or in a container packed in cast iron chips. It should be preheated to 1200 to 1300° F. and then heated to 1725° F. Sections up to 2¼ in. diameter may be quenched in still air. Sections 2½ to 6 in. are oil quenched until black and then cooled in air. Massive sections larger than 6 in. should be oil quenched to 150° F. Tempering should be performed immediately after the work cools to about 150° F. The tempering temperature varies according to the intended use. For cold work applications a temperature of 400° F. is recommended; for hot work applications, 900 to 1000° F. Time at temperature should be 1½ to 2 hr. per inch of thickness.

Metallography of a Space Traveler

*By C. R. SIMCOE**

The structure of metallic meteorites, the only known objects on earth which have traveled through space, can provide some clues to the environment of long-range ballistic missiles and earth satellites. (N general, Fe, Ni)

METEORITES have been a source of mystery and awe for centuries. These "stones from heaven" have been worshipped by some ancient peoples and feared by others who attempted to destroy them by burying them or dropping them into lakes. A few practical tribes discovered their utility and hammered them into tools and weapons.

Their source is out of this world but their exact origin is still unknown. Some speculate that they come from outside our solar system while others believe them to be fragments of a tenth planet which once circled the sun. Some meteoritists have suggested that they were formed in space from the collection of cosmic dust. Whatever their origin, they are the only objects in the world known to us that have traveled through space and passed completely through the atmosphere without being destroyed. Intensive study of their properties may be helpful in the development of both long-range ballistic missiles and earth satellites.

Scientific studies on meteorites have been carried out since the eighteenth century, and the irons were first sectioned and examined in 1808 by Widmanstätten. In fact, much of the early study of metal structures was on meteoric iron. Recent studies have been sporadic and considerable work remains to be done before the metallurgy of meteorites is understood. Actually, only about 5% of all meteorites are metallic; the nonmetallic or stone meteorites also present a very large and fertile field for further studies.

Some representative meteorites are shown in Fig. 1. Inset at the lower right on p. 73 is the 404-g. fragment from the Canyon Diablo, Ariz., meteorite fall with which we have been working. Its surface is very irregular and exhibits the characteristic markings of the irons. The white areas are crusts of sand which may be rubbed off easily. Its composition is 7.0% Ni, 0.25% P, 0.10% Co, 0.01% Ge, 0.005% Cu, 0.002% Ca, remainder iron. The other meteorites are a Henbury, Australia, iron (small one above), a Chico Hills, N. M., stone (the larger one above), and a plaster cast of the Ainsworth, Neb., iron (the large one on p. 73).

A polished and etched cross section of the Canyon Diablo meteorite is shown in Fig. 2. It has the typical Widmanstätten structure with thick plates of alpha-iron grains which are preferentially oriented along the octahedral planes

*Principal Metallurgist, Battelle Memorial Institute, Columbus, Ohio. The author wishes to acknowledge the aid of a number of Battelle staff members, especially R. D. Buchheit, who performed the metallographic work. The meteorites were furnished by Dr. Lincoln LaPaz, Institute of Meteoritics, University of New Mexico.

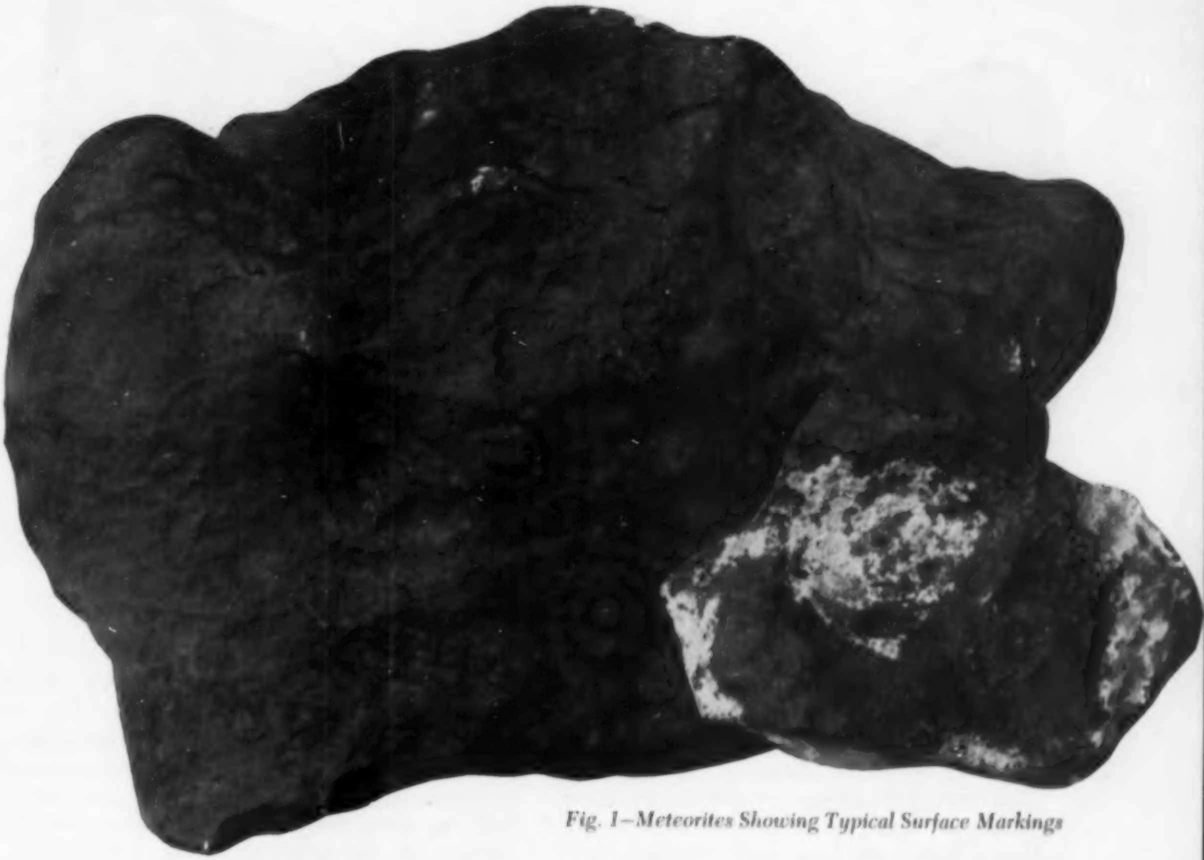


Fig. 1—Meteorites Showing Typical Surface Markings

of the gamma iron from which they transformed. This type of structure has been produced in the laboratory but the plates are not as thick as in meteorites. The large compound inclusions in the upper right portion of the macrograph (Fig. 2) are particles of schriebersite, an iron-nickel phosphide.

Since the Widmanstätten pattern shows the same orientation over the entire cross section of the meteorite, it apparently formed within a single crystal of gamma iron. In fact, most iron meteorites that have been sectioned show only a single orientation of this structure. Therefore, they must be smaller than the individual grains of gamma iron of the body from which they were produced. Such grains are fantastically larger than those in man-melted iron and it must be assumed that the original body cooled extremely slowly from liquid to solid. This cooling rate was probably maintained down through the transformation which occurs from 1300 to 800° F. for an iron containing 7% nickel. Just as slow cooling must have produced the large gamma-iron structure, it must also have produced the wide alpha-iron bands of the Widmanstätten structure.

At high magnification, a more complex structure becomes apparent which indicates that two other phase changes occurred after formation of the coarse Widmanstätten structure. Within the coarse Widmanstätten structure, which contains particles of austenite and schriebersite at the boundaries, are intermediate-size grains of ferrite. Within these grains, there is a much finer pattern of ferrite grains indicating a third transformation. The fine grains are obvious in the eight or ten intermediate-size grains in Fig. 3. The particles marked A are schriebersite and those marked B are the iron-nickel gamma phase. In the latter there is a fine precipitate of ferrite in a Widmanstätten structure.

The intermediate structure was apparently formed as a result of recrystallization of the original Widmanstätten structure. Its coarseness indicates either a high recrystallization temperature or extremely long times at a low recrystallization temperature. The latter is more likely since high temperatures cause drastic alterations in the schriebersite structure and the schriebersite in this specimen does not seem to have been altered since it originally formed. The meteorite probably recrystallized a second time to form the fine-grained structure. Again the recrystal-

Fig. 2 – Coarse Widmanstätten Structure of the Canyon Diablo Meteorite. Nital etch; 3 ×

lization temperature was not high enough to affect the schriebersite phase.

The cause of the two recrystallization processes can only be a matter for conjecture. However, either or both could have resulted from the deformation and heat produced by the disruption which destroyed the original body from which this and the rest of the meteorites in the fall were produced. It seems more likely that the intermediate structure was produced at this time and that the fine-grained structure was caused by collisions in space and cosmic heating. It has also been suggested that this final structure may have developed from heat generated as a result of entry into the earth's atmosphere and impact upon the earth's surface.

One of the peculiarities of structure is the eutectic or eutectoid-like appearance of patches of ferrite and austenite as shown in Fig. 4. The occurrence of the two phases as alternate plates

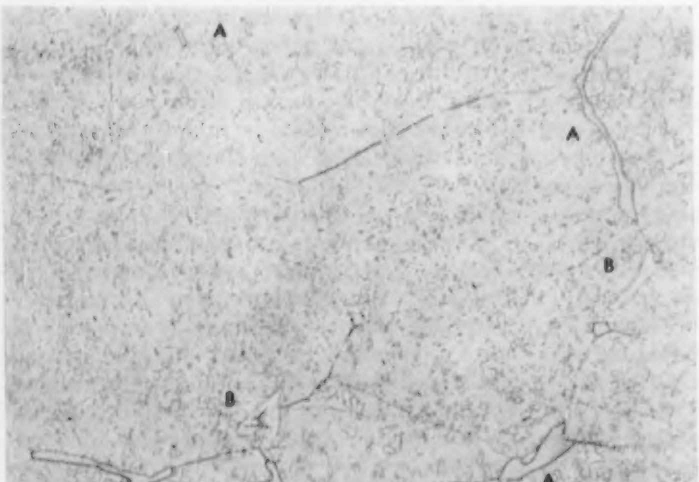


Fig. 3 – Typical Microstructure of the Meteorite. Nital etch; 50 ×. Schriebersite is marked A and austenite B

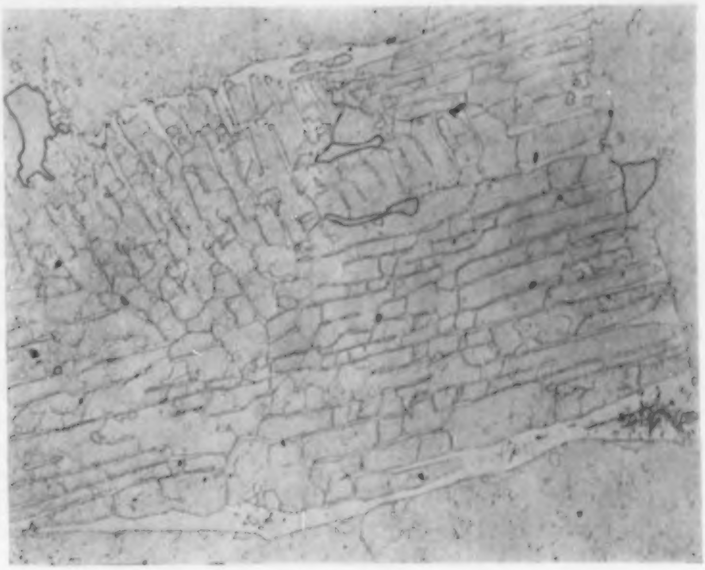


Fig. 4 – Eutectoid-Like Structure of Alternate Plates of Ferrite and Austenite. Nital etch; 100 ×

would indicate that the iron-nickel phase diagram consisted, at elevated temperature, of a single phase which decomposed by a eutectoid reaction at some lower temperature and that the nickel-rich terminal solid solution exhibited a sharply decreasing solubility for iron at subeutectoid temperatures. With these postulations, one could explain not only the presence of the eutectoid-like structure but also the formation of ferrite within the gamma-iron particles found at some grain boundaries. Unfortunately, the iron-nickel phase diagram contains no eutectoid transformation nor does it show a decreasing solubility for iron in the nickel-rich phase. It could be that the eutectoid reaction is peculair to the iron-nickel-phosphorus diagram rather than the iron-nickel diagram, but this does not seem likely because the quantity of schriebersite present suggests that it contains practically all of the phosphorus. Perhaps all that can be said is that the formation of gamma-iron plates is not understood at present but there seems to be reason for doubting the published iron-nickel phase diagram.

Attempts were made to reproduce in the laboratory the heating and cooling cycles to which the meteorite had been exposed. The first series of tests was performed by heating small specimens very rapidly by an oxy-acetylene torch to 1200 and 1500° F. and then water quenching. Only 10 to 15 sec. was required to complete this heating and cooling cycle. The second series of tests consisted of heating small specimens for 30 min. at 1500, 1800 and 2000° F. These samples were heated and cooled in air. It was thought that heating during the first series of tests might be similar to heating on entry into the earth's atmosphere and that the second might be similar to the longer times of heating that could result if the meteorite were heated by cosmic radiation or close approaches to the sun.

The structure of the sample heated rapidly to 1200° F. indicates that the meteorite had not been exposed to temperatures that high subsequent to the formation of the original coarse Widmanstätten structure, because of the two structural changes evident in Fig. 5. The fine ferrite grains coarsened and became more irregular in shape and the schriebersite either underwent a solid-state transformation or melted. The cored white particles within the massive particle indicate melting; however, there is no evidence in the literature that melting would occur at this low temperature. The melting of a mixture of artificial schriebersite of 65% iron, 20% nickel and 15% phosphorus was found to be approximately 1900° F.

Rapid heating to 1500° F. by the oxy-acetylene torch followed by water quenching further coarsened the grain and caused what appears to be eutectoid transformation in the schriebersite phase. As would be expected, the heat treatments at 1500, 1800 and 2000° F. for 30 min. produced even greater changes in the structure than did the lower-temperature shorter-time treatments. The ferrite grains were considerably coarser and

changes in the schriebersite phase were exceedingly drastic as shown in Fig. 6. A wide reaction zone was formed around the schriebersite and its structure has the appearance of a eutectic. Since temperatures of 1800 and 2000° F. are within the melting-point range for the artificial schriebersite mentioned previously, it appears that melting may have occurred in this specimen.

While carbide particles are frequently found in Canyon Diablo meteorites, they were not observed in the original fragment examined. However, carbide particles were discovered in one of the heat treated specimens. In this specimen, carbon diffused from the carbide particle into the matrix forming pearlite, martensite and bainite when the specimen was cooled. Because the original body from which this meteorite was produced must have cooled very slowly, it is not readily understood why the carbon should be present in the form of carbides. The true equilibrium structure in the iron-carbon system is iron and graphite. It would be expected that carbon in the meteorite would be in this form.

The meteorite fragment was coated with a thin adherent oxide film which was found to be gamma $Fe_2O_3 \cdot H_2O$. It is not known whether this oxide was formed during entry into the atmosphere or as a result of weathering since that time. Although this fragment had been subjected to the earth's atmosphere for approximately 50,000 years, it seems unlikely that the oxide film resulted from weathering. This deduction was arrived at from the relatively thin but adherent film and from the sharp edges and points that still exist on the meteorite. The meteorite has external characteristics which are typical of iron-base meteorites regardless of their age. At the same time, its structure at the surface or in the interior shows no evidence that drastic heating occurred during the entry of the meteor-

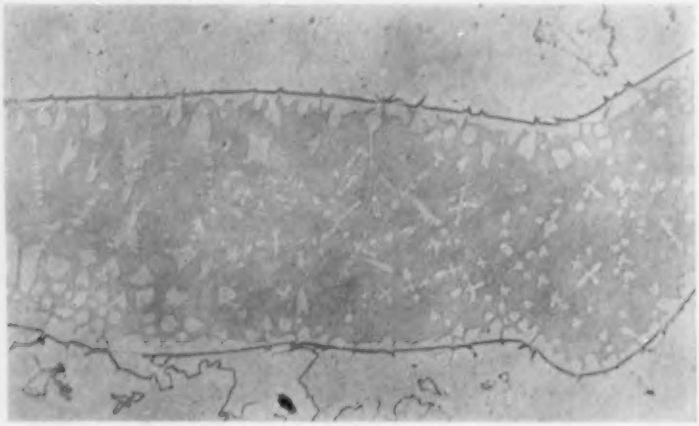


Fig. 5 – Structural Changes on Heating Meteorite Fragment to 1200° F. Nital etch; 250 ×

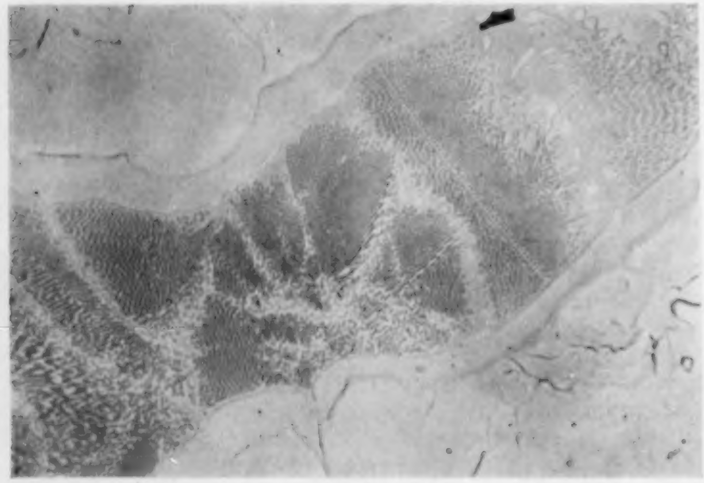


Fig. 6 – Effect of Heating Schriebersite at 1800° F. Nital etch; 500 ×

Fig. 7 – Oxidation of Ferrite Plates in Austenite at Surface of Meteorite. Nital etch; 100 ×

ite into the atmosphere. Furthermore, the existence of sharp edges and points is not consistent with some of the theories concerning high-speed aerodynamic heating.

Figure 7 shows a field at an external point of the meteorite. Originally this field consisted of alternate plates of ferrite and austenite. When oxidation occurred, the ferrite plates were converted to oxide, the gray constituent in the photomicrograph, whereas a considerable quantity of the austenite was unaffected. The resulting structure consisted of plates of gamma $Fe_2O_3 \cdot H_2O$ surrounded by nickel-rich regions of austenite. It is difficult to conceive of this happening had the oxide formed under drastic heating conditions. Further work will be necessary before the formation conditions of this oxide can be determined.

It appears that this meteorite came from a body which was slowly cooled from the molten state. It is not possible to determine even the order of magnitude of this cooling rate, but it is conceivable that it could have been as slow as 1° F. in 100,000 years. Also, cooling in the solid state must have been extremely slow through the gamma-to-alpha transformation temperature range.

It appears that the original body was still intact when the transformation was complete in the region which included this fragment. In fact, by the time the body was disrupted its temperature may have ranged from a few hundred degrees Fahrenheit down to nearly absolute zero. The strain and heat involved in the disruption may have recrystallized the original Widmanstätten ferrite to produce the intermediate structure. The temperature involved in this process was not high enough to cause any alteration of the schriebersite or austenite.

The fine equiaxed alpha-iron grains must have formed by a second recrystallization process resulting from cosmic heating or heating by radiation from the sun in space or after it was on the surface of the earth. Detailed examination of the structure of the fragment and of the effect of heat treatment on its structure showed that it could not have been heated to high temperatures, even for short times at temperatures as high as 1200° F., since the time the transformation to the Widmanstätten ferrite occurred.

Although considerable information has been obtained from past studies of the structures of meteorites, much can be learned from further studies in this field. Additional work is needed on the changes in composition and structure of the schriebersite phase on heating. Additional work is also needed on the gamma-iron phase before structures such as shown in Fig. 4 are understood. Perhaps from the structures of metallic meteorites we may increase our knowledge of their origin and of the thermal history of the bodies from which they originate. Certainly further work is necessary before definite conclusions can be made concerning the effect of aerodynamic heating during entry into the earth's atmosphere.

Machining Hard and Brittle Materials

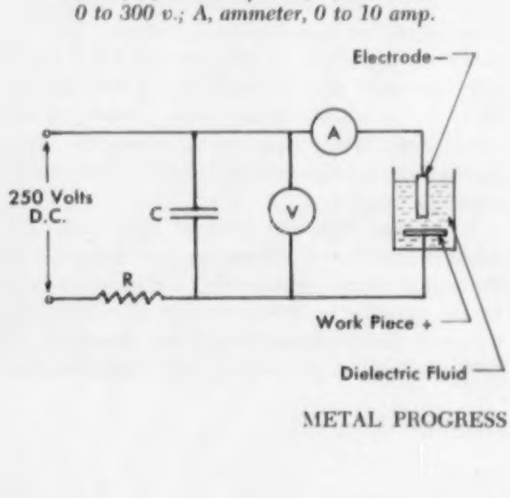
By R. C. HALL*

The laboratory equipment necessary to cut or machine hard or brittle materials by the electric spark method is simple and inexpensive to build. Metal removal rate is low but the cut surface is free from burrs and strain. (G 17)

SPARK CUTTING, sometimes called electric spark machining or electro-erosion, is a strain-free machining process with which any hard or soft material that conducts electricity may be cut. Hard materials such as high speed steels, carbides, cermets and high-temperature alloys which are difficult or nearly impossible to machine by conventional methods, may be readily spark-cut without surface cracking. Since there is no slurring of surface layers of the workpiece, spark cutting may also be used where a machining process is required which leaves no burr. In the laboratory the process may be used to cut single crystals or polycrystalline materials when a strain-free surface is essential.

Machining action occurs by the formation of an electrical arc across the machining gap, that is, between the electrode and the workpiece. A dielectric fluid such as oil, kerosene or water, is required in the gap and forced flow is beneficial in order to provide fresh fluid and to remove any small metal particles. Both the workpiece and the electrode are gradually worn away and the electrode must be replaced occasionally. High instantaneous currents occur in the arc but there is little rise in temperature of the workpiece. Williams and Porterfield have found that the

Fig. 1 – Electrical Diagram for Simple Spark-Cutting Apparatus. R, 90 ohms; C, 16 microfarads; V, voltmeter 0 to 300 v.; A, ammeter, 0 to 10 amp.



*Magnetic Materials Development Laboratory, Westinghouse Electric Corp., East Pittsburgh, Pa. This work was supported in part by the Aeronautical Research Laboratory of the Wright Air Development Center.

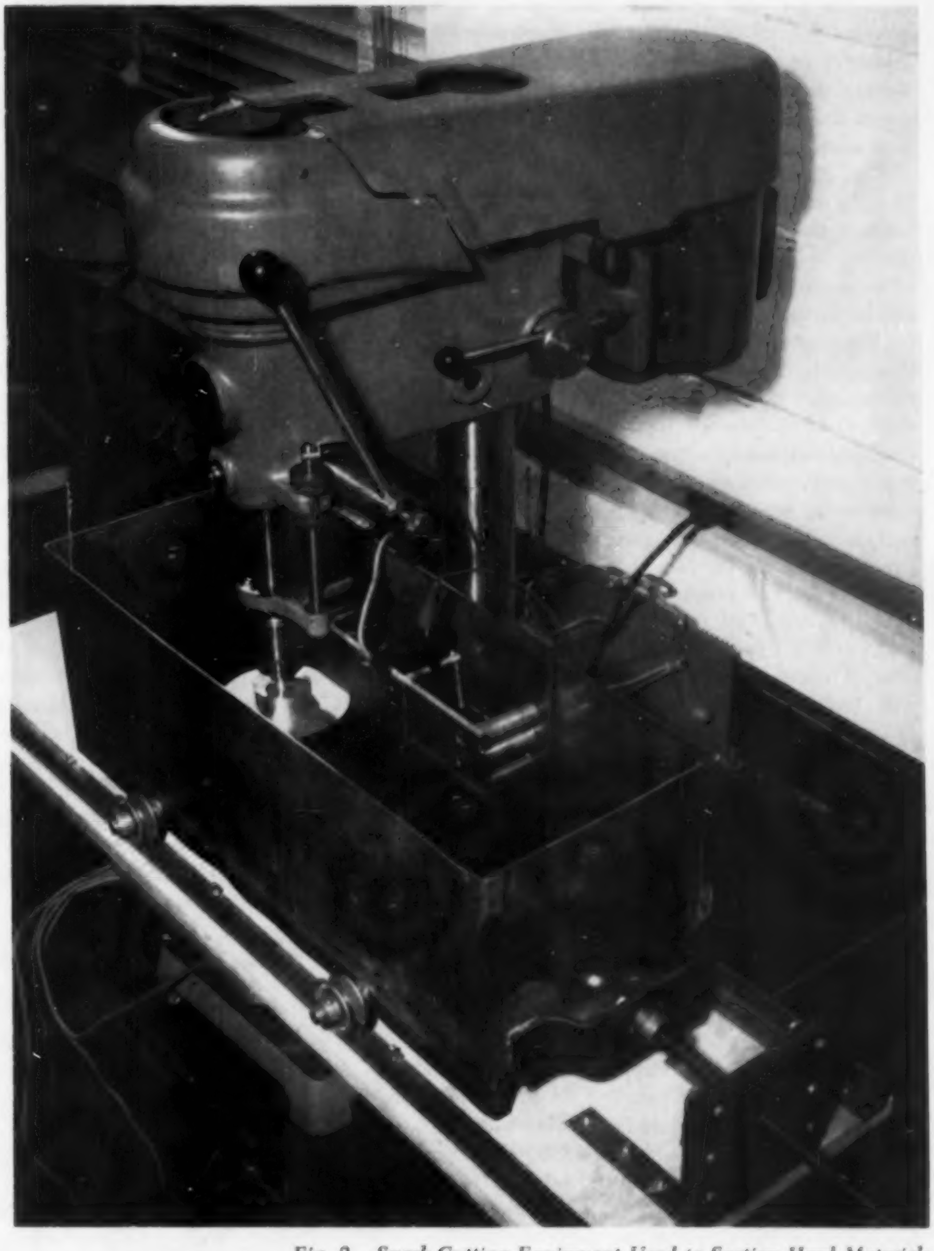


Fig. 2 – Spark-Cutting Equipment Used to Section Hard Materials

surface layer affected by the arcing rarely reaches 0.0015 in. in depth.* X-ray back-reflection patterns have indicated that no strain is produced in spark-cut single crystals of silicon iron and of aluminum. Patterns on spark-cut single crystals of 12 and 17% aluminum iron reveal a slightly strained surface.

A laboratory spark-cutting apparatus may be assembled cheaply and quickly; a satisfactory electrical system is illustrated in Fig. 1. The voltage and capacitance may be altered to vary the speed of cutting and the quality of the cut surface; a slower cutting speed (lower voltage and

*"Electric Spark Machining" by E. M. Williams and C. P. Porterfield, *Consulting Engineer*, April 1955, p. 34 to 37.

capacitance) will produce surfaces of higher quality. A spark-cutting unit was constructed for taking slices from single-crystal bars and for sectioning sheet or plate of hard and brittle polycrystalline materials such as the 17% aluminum-iron alloy.

This apparatus, shown in Fig. 2, was assembled on a drill press. The arbor of the drill press, holding the brass disk electrode, is fixed at the desired height. Revolution of the disk causes it to wear evenly and produces the forced flow of the kerosene. (The kerosene level was lowered for the photograph.) It is advantageous to use as thin an electrode as possible in order to reduce the amount of cutting action required; also the disk must rotate evenly. The workpiece is clamped to the insulating holder; in this instance it is a polycrystalline plate of 17% aluminum iron which was subsequently sliced without forming surface cracks. The tank and workpiece are advanced manually by means of the fine-threaded rod at right. The proper machining gap is maintained by observation of the voltage; if the electrode and workpiece come too close and make contact, the voltage will drop to zero and arcing will cease.

Another simple apparatus for cutting circular disks or squares from sheet material is shown in Fig. 3. The workpiece is clamped or glued to the insulating base. A hollow electrode is machined to the desired shape and kerosene is pumped down the center. The electrode may move only in the vertical direction, that is, up or down. Arcing proceeds when the electrode is lowered until the machining gap is the proper size.

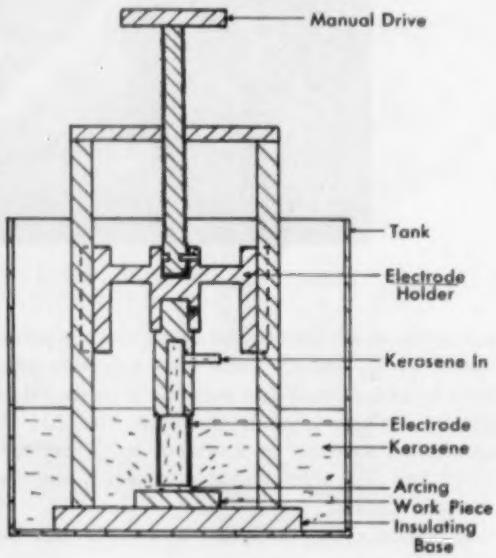
Industrial spark-cutting units have several advantages over the simple arrangements described above. The electrode may be automatically fed into the workpiece by an apparatus which regulates the rate of feed dependent on the voltage between the electrode and part being cut. The only labor required for such a machining process is that needed to make the initial setup.

Many simple or complex cuts may be made, depending on the shape of the electrode and the manner in which the electrode is applied. With apparatus similar in principle to that shown in Fig. 3, holes may be made which are round, rectangular, hexagonal, elliptical, star-shaped or any other odd shape, if the electrode can be formed initially in the desired shape. Furthermore, if the electrode is shaped on the inside, an exterior instead of interior form may be imparted to the piece; for example, small gears could be formed in one cut. More than one shape may be formed at different levels of a hole if the electrode is smaller at the entrance end. A cut does not have to go all the way through the workpiece so cavities in dies may be formed. It is possible to modify the equipment and cut threads or bore a hole which has a larger diameter contour in the middle than at either end. With apparatus similar to that illustrated in Fig. 2, the workpiece may be sliced or grooved. The groove could be formed with a special contour if the edge of the rotating disk is prepared properly.

An important industrial problem relevant to the cost of operation is the speed of machining. This can be much more rapid than that used in the simple laboratory apparatus; however, it is limited by the quality desired for the cut surface, the rate of dielectric flow and the rate at which particles resulting from the operation collect in the machining gap. According to Williams and Porterfield, the maximum rate of material removal in industrial small machining operations at present is about 0.1 cu.in. per min. This is too slow to compete with conventional machining methods employed for soft material; however, it is quite feasible for machining hard materials. Faster rates for spark cutting are conceivable if larger power units are employed and if machining takes place over larger surfaces.

Thus it would seem that spark cutting will have an increasingly important role to play in the industrial scene as its potentialities become more widely known and the process is improved.

Fig. 3 – Sketch of Apparatus for Cutting Disks From Sheet Materials



The Reduction of Ore to Metal

By L. M. PIDGEON*

Four methods have been widely used in the past, but each has its limitations. One very ancient method reappears, wherein one reactive metal displaces a less active one from a chemical compound. Magnesium and calcium are most effective as such reducing agents, and this article – the first of three – will discuss their utility. (C general)

METALS have been produced from their ores by many methods, but each has its theoretical and practical limitations. One method, very ancient, wherein one metal displaces a less active one from an appropriate compound, reappears as the most useful for producing the "new" metals used in atomic reactors, aircraft and missiles.

Ancient metallurgists gave us most of the metals of everyday use. With the exception of chromium, manganese, vanadium, and of course aluminum, no metals are now in common use which were not known for many, many years. The present century has seen the advent of a new metallurgy, the metallurgy of the "reactive" metals. These metals are so called because they readily form very stable compounds from which they are reduced or recovered with great difficulty. In the past, many of their ores were called "nonmetallic minerals" simply because they were unreducible by known methods.

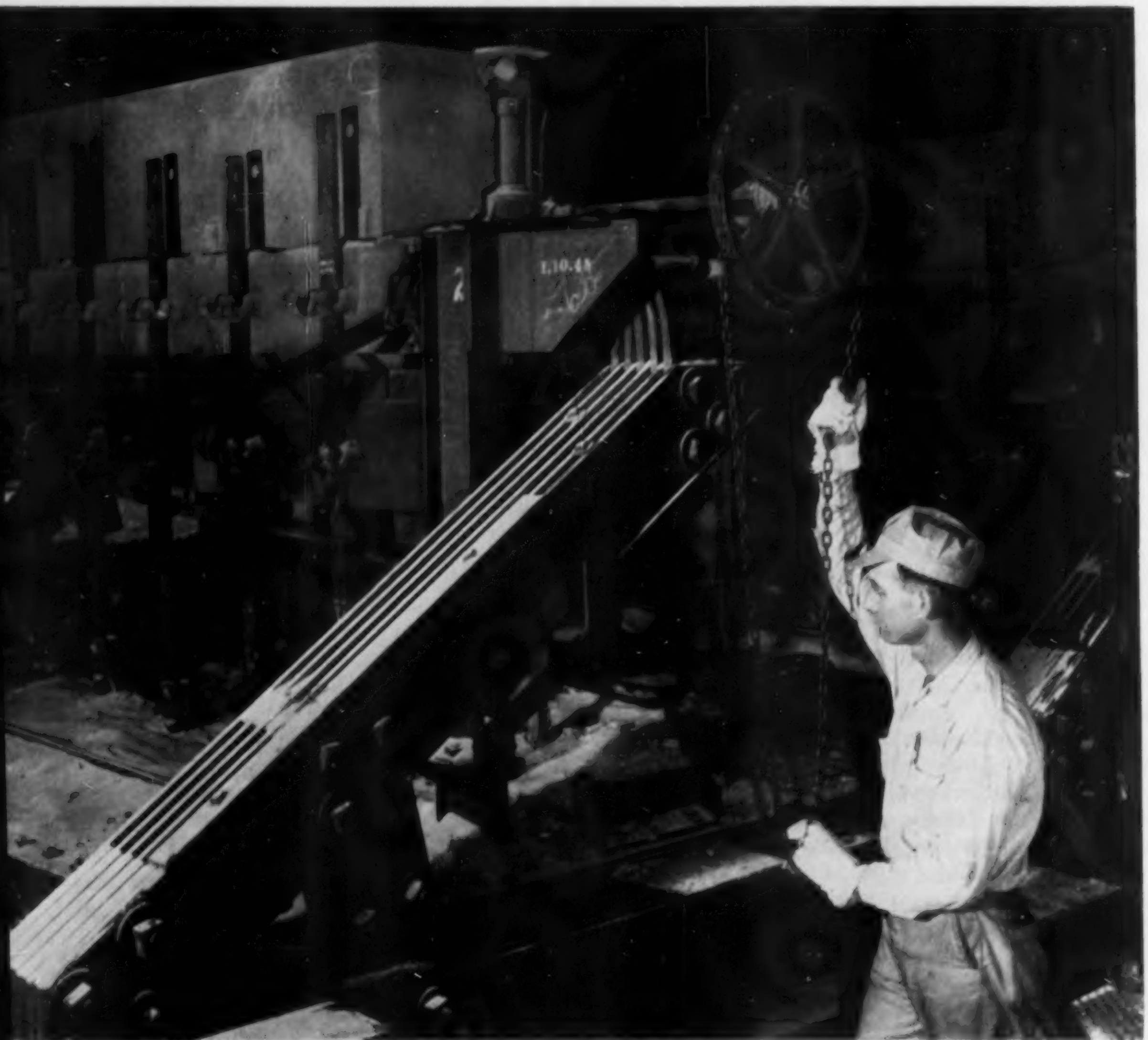
The reactive new metals show no other similarities. Some are hard, some (like titanium) possess high melting points, others (like lithium) are soft and melt at very low temperatures. Densities show the widest range – from 0.5 for lithium to 19 for uranium.

Two major activities of our times have produced a new demand for these reactive metals. First, the airplane, and in fact anything which flies through the air, including guided projectiles, demand lightness, and all the light metals meet this requirement. Second, nuclear energy has imposed an entirely new list of demands upon the metallurgist, both for fissile materials and for structural materials for the nuclear reactor. Prominent among the metals meeting these special requirements are uranium, plutonium, thorium, zirconium and beryllium.

It is interesting to note that magnesium and calcium have been used widely as reagents for the reduction of the above metals from their chemical compounds – in fact magnesium and calcium are almost the only reagents so used in a commercial way. Aluminum, silicon and sodium have been used in certain isolated cases. However, most of the reactions involved have been known for a century or more, but only recently has the demand for special metals justified the development of techniques and devices to produce them in quantity and in a satisfactory chemical and physical state.

It therefore seems opportune to review the entire situation, and this will be done in three short articles, the first of which will discuss in simple terms the general problem of the reduction of compounds to metal. The second will describe the scientific principles underlying one of the four possible methods – namely the production of metals by reactive metal-reducing agents – and the third will give some practical applications of these theoretical principles in the production of "new" metals in quantity.

*Professor of Metallurgical Engineering, University of Toronto.



Close-up of Cell or Pot for Electrolytic Production of Aluminum. Direct current is led through inclined busbars to hangers carrying carbon electrodes (almost completely hidden below snowy alumina level with the top). Alumina dissolves in molten cryolite, the electrolyte, and dissociates when current passes from electrodes to carbon lining of pot. Aluminum collects on the bottom; oxygen combines with the hot carbon electrode.

Available Methods – The recovery of a metal from its ore generally involves three steps:

I. Separation of the metal-containing mineral from surrounding rock or gangue. This is preferably a physical process and includes operations such as crushing, sorting, screening, flotation, magnetic methods, jigging, all of which rely on differences in physical behavior between the ore particle and the surrounding gangue.

II. Preliminary chemical treatment, which produces a compound suitable for reduction to the metal. A common example would be the roasting of a sulphide ore. For the reactive metals this step is generally carried as far as possible to produce a pure compound of the metal free from other components which would react and contaminate the desired product during subsequent processes.

III. Reduction to metal. The reduced metal must be separable from other products of the

Table I – Free Energy of Formation of Oxides (per Oxygen Atom)
(J. P. Coughlin, U.S. Bureau of Mines Bulletin No. 542)

At 227° C.		At 727° C.		At 1227° C.		At 1727° C.	
Ag	+0.06	Cu	−23.3	Cd	−14.4	Na	−7.9
Hg	−8.8	Pb	−28.7	Cu	−15.2	Cu	−10.7
Cu	−31.5	Ni	−35.0	Pb	−18.7	Ni	−13.0
C(O)	−37.1	Cd	−37.7	Ni	−24.2	Zn	−15.0
Pb	−40.4	Co	−38.8	Co	−29.5	Co	−19.9
Ni	−46.1	Fe	−47.8	Na	−38.6	Fe	−33.8
Co	−47.9	C	−47.9	Zn	−38.9	Cr	−49.1
Cd	−50.4	Zn	−61.4	Fe	−40.0	Mn	−55.1
Fe	−55.5	Na	−65.5	C	−58.3	U	−59.6
Zn	−71.3	Cr	−69.7	Cr	−59.5	V	−60.5
Cr	−81.6	Mn	−74.5	Mn	−65.6	Si	−61.9
Na	−83.0	V	−79.0	V	−69.5	C	−68.5
Mn	−83.1	Si	−83.4	Si	−73.1	Ti	−70.1
V	−89.0	Ti	−91.1	Ti	−80.5	Mg	−76.1
Si*	−94.0	Al	−108.2	Li	−92.0	Al	−82.0
Ti†	−101.2	U	−109.0	Al	−95.1	Ba	−86.0
U‡	−119.1	Li	−110.2	U	−98.8	Ca	−95.5
Al	−120.7	Ba	−110.5	Ba	−99.0	Be	−96.6
Ba	−121.5	Mg	−117.7	Mg	−101.3		
Li	−127.7	Be	−119.6	Be	−108.3		
Mg	−130.8	Ca	−126.0	Ca	−113.3		
Be	−131.3						
Ca	−138.2						

*Quartz †Rutile ‡The dioxide, UO_2

reaction, and it may be subjected to subsequent purification processes usually called "refining". The latter is, however, rather uncommon for the reactive metals, since intensive refining operations are applied during the preliminary chemical treatment (step II).

Perhaps a few side remarks or definitions are appropriate at this point. The word "ore" has been used above. Webster defines ore as "any material containing valuable metallic constituents for the sake of which it is mined and worked". The definition fittingly includes the idea of profit – for example, an ore which is now profitably mined for copper would be waste rock prior to 1900; we have meanwhile developed crushing and concentrating methods whereby sufficient of the gangue is rejected so we can smelt the concentrate and still come out on the right side of the ledger.

Whenever ores may be beneficiated, it is always done because of its inherent cheapness. However, few ores of the reactive metals are amenable to such treatments involving physical separations; much more expensive chemical methods must be applied. As we have said, the actual reduction step is usually so difficult that purification is carried as far as possible prior to reduction, and the reduction step itself is so arranged that the reduced metal is so little contaminated that subsequent refining is unnecessary. High-purity reducing agents are of course essential; fortunately magnesium and calcium are obtainable in this condition.

In this article "production" of metals will refer to the separation of the metal from an appropriate compound. The previous and essential steps required to produce this compound are outside the immediate scope of this paper.

Common methods of metal production fall into four groups, which will now be named and briefly discussed.

1. Thermal decomposition is theoretically possible for all metals, but is most practicable for the "noble" metals whose oxides exhibit positive free energies of formation* under standard conditions at low temperatures. Gold, silver, platinum and mercury are examples, and their presence as native metals in the earth's crust is a consequence. Thermal decomposition has been used in the metallurgy of the more reactive metals in special instances where volatile salts may be decomposed on a hot surface – such as the deposition of titanium from gaseous titanium iodide. The carbonyl process for nickel also involves thermal decomposition of gaseous $Ni(CO)_4$.

2. Reduction of Oxide with Carbon, Carbon Monoxide or Hydrogen—Fortunately, many oxides may be readily reduced to useful metal by carbon and its lower oxide, carbon monoxide. Excluding the noble metals, the metals known since ancient times have all been produced in this manner – in fact, carbon will reduce all oxides, as was shown by Borchers in the 19th cen-

*It is a well-known scientific principle that the most stable state of any system is that having the lowest energy. Since heat is a form of energy, any change which results in the liberation of heat will result in a more stable state. The few oxides of the noble metals all decompose with liberation of heat; hence, under standard conditions, the metals themselves become the stable phase. The usual values for free energy of formation are expressed in terms of kilogram-calories per mole of the compound at 25° C. The most accurate values are now listed in various circulars of the U. S. National Bureau of Standards. (See also the new edition of Kubaschewski and Evans.) Table I shows values of the standard free energy of formation of various oxides, and is taken from Coughlin.

tury. This is the reason why no "nonmetallic" minerals exist. Nevertheless, the classical reaction

$$MO+C=CO+M$$

is incapable of producing M, the metal, in a pure state when the free energy of formation of MO becomes high. For example, Table I shows that the free energy of formation at 727° C. (1340° F.) of copper oxide is −23.3, of lead oxide is −28.7 and of carbon monoxide is −47.9 kg-cal., so there is no difficulty in reducing these minerals with carbon at that temperature. Furthermore, iron oxide can be reduced completely by carbon at 1227° C. (2240° F.) because the respective free energies of formation of iron oxide and carbon monoxide are −40.0 and −58.3 kg-cal. at that temperature. However, reduction of uranium (−98.8 kg-cal.), silicon (−73.1 kg-cal.) manganese (−65.6 kg-cal.) or chromium (−59.5 kg-cal.) by carbon (CO, −58.3 kg-cal.) could not be expected at 1227° C.

The application of the results of Table I to the reduction of ZnO by carbon is as follows:

Temperature	ΔF° for ZnO	ΔF° for CO
227° C.	−71.3	−37.1
727° C.	−61.4	−47.9
1227° C.	−38.9	−58.3
1727° C.	−15.0	−68.5

Obviously zinc oxide could not be reduced by carbon monoxide until about 900° C. is reached. This is about the boiling point of this metal, and zinc, by the way, is the most "reactive" metal which may be produced by carbon reduction entirely in a fuel-fired furnace. It is, in fact, a fairly "recent" metal – having been first produced as metal in early modern times. (It had long before been reduced simultaneously with copper to form a brass.)

As above remarked, SiO_2, MnO, and Cr_2O_3 are not readily reducible by carbon in fuel-fired furnaces, and they were not produced effectively before the development of the electric furnace. At the higher temperatures there available, carbon will reduce these and the oxides of even more reactive metals. Unfortunately, a new stable compound is likely to appear at the high temperatures – namely the carbide of the metal. These carbides have very high melting points, as shown in Table II.

Table II – Some Thermochemical Data for a Few Important Metals and Carbides

Element	ΔF (Oxide)	ΔF (Carbide)	M. P.
C	−68.5	—	—
Si	−61.9	−26.1 (SiC)	—
Mn	−55.1	—	—
Cr	−49.1	−16.5 (Cr_4C)	—
Ti	−70.1	−53 (TiC)	3130
V	−60.5	—	2770 (VC)
Zr	—	−45 (ZrC)	3440
U	−59.6	−42 (UC_2)	2430
$CaC_2 \cdot CaO$	—	—	1970

ΔF (oxide) is free energy of formation of the oxides at 1727° C. (3140° F.)

ΔF (carbide) is free energy of formation of the respective carbides at 25° C.

M.P. is melting point of the carbide, ° C.

Many metals (silicon, titanium, zirconium, thorium, aluminum, manganese, uranium) form various amounts of carbides during the reduction of their oxides by carbon. If a solvent metal is present, however, the metal which is wanted may be obtained as a solute; such a procedure forms the basis of the ferro-alloy industry. Ferrosilicon, ferrochromium and high-manganese ferromanganese are obtained by reaction of the appropriate oxide with carbon in the presence of iron in the electric arc furnace. Even in these systems, a carbon-free alloy is not always produced; for example, low-carbon ferrochromium requires special procedures.

Table III – Electromotive Force*

Metal	Valence	Electrode Potential
K	1	−2.922 volts
Ca	2	−2.87
Na	1	−2.712
Mg	2	−2.34
Be	2	−1.70
Al	3	−1.67
Mn	2	−1.05
Zn	2	−0.762
Cr	3	−0.71
Ga	3	−0.52
Fe	2	−0.440
Cd	2	−0.402
In	3	−0.340
Tl	1	−0.336
Co	2	−0.277
Ni	2	−0.250
Sn	2	−0.136
Pb	2	−0.126
H_2	2	0.000
Cu	2	0.345
Cu	1	0.522
2Hg	2	0.799
Ag	1	0.800
Pd	2	0.83
Hg	2	0.854
Pt	2	1.2
Au	3	1.42
Au	1	1.68

*From "The Corrosion Handbook", Edited by Herbert H. Uhlig, John Wiley & Sons, Inc., N.Y.

Since the potentialities of carbon as a reducing agent have long been exploited to the full by very ingenious smeltermen, it seems unlikely that pure metals of the reactive modern group will be produced in this manner, although carbon reduction may constitute a preliminary reducing

step, followed by refining. An interesting possibility is the production of ferro-aluminum from clay, followed by extraction of aluminum from the ferro-alloy, as proposed by P. Gross on p. 206 of his book "The Physical Chemistry of Process Metallurgy":

$$2\ FeAlSi + AlCl_3(gas) = 3\ AlCl(gas) + 2\ FeSi$$
$$3\ AlCl\,gas) = 2\ Al + AlCl_3(gas)$$

3. Electrolysis is a modern method of producing metals, the endowment of Michael Faraday. While virtually all metals can be electrodeposited, the facility varies greatly. Sometimes the metal results from a secondary electrode reaction, whereupon the advantage of the combined process may often be questioned.

Electrolysis requires an ionized solution and usually operates under most favorable conditions when the solution is aqueous. Ionized aqueous solutions of the wanted metal are often producible by simple acid leaching, and required purity is readily obtainable in the deposit by precipitation of unwanted ions prior to electrolysis. By trial and error method, the trick of producing dense, coherent metal deposits has been mastered, sometimes by additions of gelatin, "goulac", or other compounds to the electrolyte.

Metals below manganese in the series shown in Table III may be deposited from aqueous solutions. Above manganese, the hydrogen overvoltage phenomenon is insufficient to prevent the decomposition of water, and nonaqueous electrolytes must be used. Many molten salts are satisfactory, although they are invariably more difficult to produce than their aqueous counterparts, and the electrolytic operation loses its operational simplicity. As the wanted metal nears the head of the electromotive series, the number of "noble" impurities increases, and electrolysis becomes less able to produce a pure metal. Occasionally, salts with attractive physical properties are not ionized in the molten state, and a carrier ion must then be introduced.

Perhaps the most serious objection to electrolysis with molten salt baths appears when the wanted metal has a high melting point. (For example, the melting point of titanium is above the boiling point of most of the electrolytes which can be considered!) A solid-state deposit is then inevitable; it seems that a coherent deposit from a nonaqueous electrolyte cannot be produced. Thus the "trees" of electrolytic zirconium and flakes of electrolytic beryllium are unfavorable physical forms for subsequent use of such reactive metals. "Tree growth" seems inherent to solid-state electrodeposition; it is suppressed by gelatin and the like in aqueous solutions, but no "goulac" suitable for molten salts is available.

For these and other reasons, electrolysis has yet to prove itself an effective method of producing the metals of Group IV, the rare earth group, beryllium, uranium, and others.

4. Displacement with another metal goes back to the early history of metallurgy. The cementation of copper by iron was employed at the Rio Tinto mine in Spain in Roman times.* The reduction of lead oxide by iron in the lead blast furnace is a more recent pyrometallurgical example.

The use of powerful reducing agents in oxide systems is, however, a modern development and stems from Goldschmidt's invention of the "thermit" reaction:

$$Fe_2O_3+2\ Al=Al_2O_3+2\ Fe$$

Similar reactions in halide systems were employed by Bussy in 1830 to produce magnesium, and by St. Claire Deville in 1855 to produce aluminum:

$$AlCl_3\cdot 3\ NaCl+3Na=Al+6\ NaCl$$

These displacement reactions in oxide and halide systems are now being used in increasing extent to make small quantities of the lesser-known metals. In the metallurgy of titanium, at least, the same reactions have reached commercial proportions, and many thousands of tons of magnesium have been consumed in this manner.†

It is hoped that this simplified statement of metallurgical principles will not appear too elementary, but rather that it will be a "refresher" to those many readers of *Metal Progress* whose daily work is a long way from the primary work on the metals they handle. At least it has been thought desirable to make this presentation so that the advantages – as well as the limitations – of magnesium and calcium as reducing agents can be put into proper perspective.

The second article in this series will present some of the limitations which chemical and thermodynamical laws have thrown about this new phase of the metallurgical art.

*At the present day, mine waters or tailing-pile seepage in copper districts are run through launders containing scrap iron; the iron goes into solution; an equivalent amount of copper deposits as a sludge.

†In addition to the four groups discussed in this article, large tonnages of copper are produced by a double decomposition reaction which is generally stated to be

$$Cu_2S+2\ Cu_2O=6\ Cu+SO_2$$

This reaction is available for lead and other non-reactive metals, but is used commercially only for producing copper.

1955 Recipient
Albert Sauveur Achievement Award

William Justin Kroll

A Biographical Appreciation

By EARL T. HAYES

PRESENTATION to William J. Kroll, best known for his work on titanium and unusual metals, of the Albert Sauveur Achievement Award for 1955, emphasizes the fact that there is only one world of metallurgy today. Most of the previous medalists have been renowned for their contributions to the knowledge of iron and steel; seldom has the committee departed to pick a nonferrous metallurgist. However, in his thousands of metallurgical experiments, his 150 papers and patents in Germany, France, England and the United States and his international background, Kroll is a living example of the fact that science knows no boundaries.

Geneology might prove that Kroll was predestined for this award because his father was a blast furnace plant manager and one of his grandfathers operated an iron ore mine. He grew up and was educated in the old storybook city of Luxembourg and then spent the years from 1910 to 1917 at the Technische Hochschule in Charlottenburg, Germany, where he seriously studied iron metallurgy under one of the masters, W. Mathesius. However, his thesis had to do with the preparation of elemental boron, and this led him away from iron and steel forever into the land of the little-known metals, titanium, zirconium, beryllium, uranium, that have become both fashionable and useful in the last decade.

The large German firm, Metallgesellschaft, was Kroll's first employer at a lead refinery in the hills near Frankfurt-am-Maine. During his two years at this place he hit upon a calcium-lead alloy that proved to be an excellent agent for removing bismuth from lead. With certain improvements added by Betterton of the American Smelting and Refining Co., this eventually emerged as the Kroll-Betterton process, now widely used for debismuthizing lead.

In 1919 young Kroll went to Vienna and set up a plant for recovering the gold, silver and tin from residues left after the copper had been recovered from scrap – principally church bells. Two years spent in building a metallurgical plant – including a reverberatory furnace, converters, shaft furnaces, bag houses and electrolytic cells – prepared him for a lifetime of developmental work on the whole field of nonferrous metallurgy. It also left him with many pleasant memories, because his dark eyes take on a certain fire as he reminisces of the wine, women and the good food of old Vienna.

In 1922 he joined a small foundry near Baden-Baden, Germany, and helped develop an aluminum piston alloy of low expansion, as well as a magnesium-base alloy containing up to 6% misch metal. The firm of I. G. Farben resurrected the last-mentioned from the files and put it to practical application during World War II.

After these 13 years in the hinterlands, Kroll went back to Luxembourg and founded the laboratory, Bel'air, where he spent the next 17 years. With the help of a mechanic, a laborer, and a secretary, he reduced to patents or writings hundreds of ideas which were destined to have their effect in all metallurgy. Among these were vacuum dezincing of Parke's process residues, age hardening of aluminum-silver alloys, aging of lithium-aluminum-zinc alloys, age hardenable magnesium-germanium-aluminum alloys, the discovery that germanium crystals could replace silicon for radio detectors (this was the forerunner of the present transistor), reduction of anhydrous beryllium fluoride with magnesium (now the primary production process for beryllium).

This beryllium discovery led to a working agreement with Siemens and Halske for work in the broad field of "rare metals". When Heraeus Vacuumschmelze was taken over by Siemens and Halske this association ushered in a long list of accomplishments in vacuum metallurgy. Kroll was one of the first to make high-purity calcium, and he used this as a reducing agent to produce titanium, zirconium, uranium and thorium in the form of powder or sponge. This knowledge of vacuum purification was extended later to include silicon, copper, iron, chromium, beryllium and alloys of copper, tin and lead.

The titanium process which bears Kroll's name is his best-known contribution but only one of his outstanding technical developments. It had the good fortune to arrive in a world of science

and expanding metallurgy at a most opportune time. He first worked on titanium as far back as 1930 and produced about a pound of it by sodium reduction of titanium tetrachloride. In 1932 this was shown in rolled sheet form to a number of large companies in the United States but business was so quiet in those days that the only sounds heard were those of the dividends passing in Wall Street. No interest could be aroused. Five years later, nothing daunted, Kroll devised a "pressureless" method for reducing titanium tetrachloride with calcium and later magnesium. (In 1938 experimental runs on zirconium were made.) In that same year he visited the United States with hopes of interesting industrialists in his titanium process. There is a story that the patent could have been bought for such a small sum that, if true, it might lead to mass suicide of several promoters! At any rate the process remained dormant until the middle 1940's, when the U.S. Bureau of Mines produced titanium on a larger scale, and more fully publicized the interesting properties and possibilities of the metal. It is now a quarter of a billion dollar industry and still growing.

Kroll left Luxembourg early in 1940 just ahead of the Nazi invasion, and spent the war years with Union Carbide Research Laboratories in Niagara Falls as a consultant. One investigation of those years concerned the production of various metal powders by fused salt electrolysis and this method appears to have great promise at the present time for reclaiming zirconium and titanium scrap.

In 1944 Kroll found a receptive listener for his ideas about zirconium in R. S. Dean, then chief of the metallurgical division of the Bureau of Mines, and a year later he started the zirconium investigations of the Bureau at Albany, Ore. Four years later, when the Atomic Energy Commission in 1948 wanted to explore the possibilities of zirconium as a construction material for nuclear reactors, the basic production process had been worked out and needed only to be expanded and refined to furnish the quantities of metal needed.

There is some disciplined quality about genius or inventors of this type which never ceases to amaze the ordinary mortal. There come memories of Kroll talking to a geologist who was making some thermal analyses of obscure clays and pointing out to him, who thought he might be on the verge of some great discovery, that he (Kroll) could name the article, the authors and the magazine in which a similar investigation had been described at least 20 years previously. There are other memories, too, of "Did you ever think of doing it this way?" or, "It might work, but read so and so", or, "It might work, why don't you try it?" and all the while he knew that it had been tried 10 to 40 years ago and yet was using the touch of an old master to tutor his pupils.

What of Kroll's family? He married science at an early age and has remained a true monogamist all his life; no other love has interfered. For over 40 years he followed a back-breaking schedule where 40 hours marked only the first half of the week. Between times there were periods of relaxation and these have become a little more frequent in the last few years. He has a sister and two brothers, one in San Diego and the second in Belgium who is an eminent metallurgist in his own right.

Dr. Wm. J. Kroll is now a U.S. citizen and lives in the college town of Corvallis, Ore., in the Willamette Valley which he describes as having the world's best climate. He shows, and enjoys perpetually, the scenic beauties of the rugged Oregon coast and the mountains, and tells his friends about them with all the spirit of a local Chamber of Commerce director. Like some well-known statesmen of our time, he has true ability as a painter and it is not unusual to find him somewhere in the country painting landscapes.

"Seven cities warred for Homer dead,
Cities through which living Homer begged his bread"

are lines which do not apply to Dr. Kroll because his contributions and abilities have been widely recognized in recent years. The Franklin Institute awarded him the Francis J. Clamer award; the A.I.M.E. the James Douglas medal; Deutsche Gesselschaft für Metallkunde the Heyn award; A.S.M. the Albert Sauveur Achievement Award; the University of Grenoble an honorary degree.

In a day when industrial research teams are scouring the country for information to develop into commercial practice, and when the output of original ideas (otherwise known as fundamental research) is sinking in proportion, Dr. Kroll stands out as one of the great original metallurgists of our time. Certainly no one could have assigned him a finer contribution to metallurgical knowledge than the discovery of ductile titanium – yet this man, working with a minimum of equipment, functioning almost as a one-man research team and driven by the love of his work, has provided us with working ideas for a whole generation of metallurgists.

Light Metallurgy . . .

"Plates Will Be the Death of Me"

*By D. CARB**

I'M IN RUDY'S putting on the feed bag which involves a very crazy dish of pizza with grated cheese on the top and some cold meat balls on the side when I spy an old friend and business acquaintance coming through the door. This person is none other than Slivers MacCluskey whom I don't see for some time and which I don't particularly wish to see now as we recently ship him some forgings which were not quite up to par. In fact Slivers very plainly says at the time they are a long way from par in a manner which indicated he is highly displeased.

As Slivers is not a character to be displeased and noting that he comes through the door without first bothering to try the latch which fortunately wasn't latched, I figure if possible I should remain unnoticed.

I'm trying to hide behind Rudy's menu which is not exactly made for such things when Slivers stops at my table and says how am I and what brings me here and such talk in a loud and

ungentlemanly manner. I make every pretense of being pleasantly surprised and welcome him in a very cordial manner and ask if he won't tarry a while which he promptly does much to my alarm.

*With apologies to Damon Runyon.

Slivers is known far and wide but particularly is he known in our valley as an exceedingly tough character, especially in his business which is the fabrication of steel plates and parts into various and sundry things they peddle here and abroad as the finest such contraptions made anywhere. I remember one case down in Mexico some years back of some equipment made by his outfit which springs a leak at the wrong time. The leak enlarges quickly so as to make a very nice explosion and this causes the demise of numerous hombres who happen to be siestaing nearby. The incident causes Slivers to become so despondent that everyone fears for his health. He broods over this for some time but finally recovers, which goes to show he certainly takes his racket seriously and is quite conscientious and all that.

The only thing that keeps Slivers from completely going off the beam is the redeeming fact that this explosion is by far the biggest bang ever heard in Mexico and Slivers takes considerable consolation from this feature. Many times he recalls with pride that only his stuff is capable of such a bang, a unique type of advertising and one that can be substantiated as Slivers collects the obituary columns of the local blatters which tell in exact detail just how big this bang is.

Although I'm not anxious to continue our discussion as Slivers any minute may recall our last forgings delivery, the only thing to do is order him a slug which he immediately tells Rudy to double and bring a few brews to serve as chasers.

Slivers is an odd name and he comes by this handle because early in his career he becomes most adept at spotting defects on steel plates, universal or otherwise, which his company also chews up in great quantity. So adept is Slivers in fact that some of the producers whose material he is always rejecting try to get him on their payrolls as they figure they would be much lettuce ahead by just paying him to sit next to a coke-jack somewhere in one of their mills and not lift a finger. Slivers however is wrapped up in his profession as he would rather reject plates than do almost anything except maybe sit in Rudy's and commune with the spirits. So he turns down all the platemakers' offers which is really remarkable as Social Security isn't in yet.

I notice Slivers is more than usually all-out in stowing away the snorts Rudy is making to my account, and although I have finished off the last trace of pizza I have no alternative but to remain seated and listen to Rudy tolling the marks on his register and at the same time remain pleasantly sociable to Slivers, a disagreeable situation indeed.

Slivers is very plainly on the muscle at somebody or something and in the interest of bringing things to a head and thereby hastening my making a proper exit I say, "My friend, you seem vexed." "Vexed," he yells and slams a stein down on the table top, simultaneously yelling he is just plain mad. He doesn't have to add stark raving as this I can see. From experience I learn that to a guy like Slivers my next question should not be an inquiry as to what brings on his beef – in fact I learn long ago I should not even utter a next question as Slivers will take the whole thing from here.

With a visible effort to control himself Slivers says that plates will be the death of him yet. I remark that this strikes me as peculiar as after all a plate is rather a simple affair. Slivers says hell yes but so are all the people connected with them.

He brushes a few shot glasses onto the floor and starting with gestures demands what makes a plate pull a certain strength. I quickly say "chemistry" and he clouts my shoulder out of place and in a wide toothy grin pronounces me a smart fellow.

Slivers pulls out a bob, lays it on the table, and shouts to Rudy to serve suds all around. Now that I start to think about his question it occurs that things other than chemistry can affect the strength of a plate but I had damn well not bring them up at the moment.

Slivers hitches his chair closer to mine and in confidential tones that shake the joint he whispers that if chemistry is what gives a plate

strength there has to be a good connection between them. "Okay," Slivers says, these master minds who make plates will take an order to furnish the things at certain strengths or they will furnish to maximum chemistries, but the rumpots won't even listen to figuring chemistry and strength in the same plate and won't that scald my barnacles?

Now I frown on after-hours' discussion of business matters, particularly matters not mine, and more so still do I frown on loud talk in public with such characters as Slivers. So much do I dislike this situation that I'm wondering if I can make the door fast enough to escape a pursuing chair when our table is suddenly in the shadows. What causes the shadow I quickly see is a mountainous frame topped with a square bald head, king's size, and belonging to none other than a local person known as the Skull. Now the Skull is the roughest toughest melter foreman ever to knock out a heat in anybody's openhearth, and what's more, he is reputed to be a man who knows why he taps although from his name you might be led to believe otherwise. Nobody however with sound wiring would ever say so to the Skull unless his accident policy specifically covers total disability with special paid-up benefits.

Slivers maybe don't notice the new arrival and alludes that he thinks the real reason these outlaws who hijack him for plates have such a cockeyed policy is because the plumbers who melt the stuff never know what they just made in the openhearths until the direct-reading spectometers spit out the printed analysis. At the last remark, the Skull swallows the lump that was in his right cheek and eases into the protesting chair next to me and Rudy frantically grabs the phone. I involuntarily stand up but find I can't move my feet, and being suddenly weak I slump back in the chair just as the Skull says to Slivers, "Continue, chum," in a voice that reminds me of a hacksaw working on a piece of gray iron.

Slivers calmly empties the stein without even looking up and then glaring at the Skull says he intends to. The other customers are all over helping Rudy look up the number of the riot squad and I meekly ask do they think the Pirates have a chance this year. They sit there just like a chess game for what seems a long time and the Skull finally asks Slivers how he would specify that they make his stuff. Slivers shoots back, "To a standard chemistry spread for a certain strength level, extrapolating you dope." The Skull answers that they make plates to such specs so what is Slivers talking about. Slivers retorts that yeh they make them but he has to pay all kinds of fancy extras and adds that he is talking plain structural plates. The Skull bends over toward Slivers and patronizingly says that's exactly what he is getting. Also if Slivers wants chemistry restrictions and physicals in the same piece, say so on the order and they will give him a fully killed, hot-topped product, fine or coarse-grained, that double converted will satisfy him or anyone.

Slivers retorts that even if by chance they make a good ingot that way so what – the same guys roll them so he still gets all the defects he gets today. The Skull says a few scratches won't hurt anybody. "Scratches, hell!" shouts Slivers.

The next few minutes they engage in a violent discussion of what is a lamination and finally Slivers rejects the whole subject as he holds that whatever the defects are he doesn't want them and can't be expected to use such material. The Skull whose voice is becoming higher in direct ratio to the length of the conversation tells the world and Slivers that if he wants such a high quality product he should be willing to pay for it and that they can't be going through fancy deoxidation and teeming practice not to mention extra discard and inspection because some customer has a burr in his speech.

Further the Skull yells that Slivers welds the plates and bends the hell out of them, which again demands better than Structural Grade, and that he thinks Slivers had better liquidate before his customers catch up and make him insolvent.

With that insinuation Slivers loses the last vestige of control and stands up so as to do a

better job of pulverizing when much to Rudy's relief and mine, Murphy and Shultz of the riot squad saunter in and quietly bash their night sticks on the bar to indicate their presence. The Skull, who is a pinch thinker, loudly invites Slivers to sit down and join us which he does without hesitation and we are as we were with the exception of Rudy who is now trying to find one of the bottles he so quickly ducked in a safe place a few minutes before.

The Skull politely inquires of Slivers what he wishes to drink, and if he has encountered any occasional light laminations lately in their product. Slivers discreetly mumbles that it's only occasionally they don't encounter laminations and they are never light.

The Skull is paying Rudy who has ventured out from behind the bar. Slivers opines that from the homogeneity tests they have been taking he can't tell whether the Purchasing Department is buying steel or plywood. The Skull counters that if Slivers would take the trouble to come up to date he could make his old equipment with thinner plates and then the Skull could pour smaller ingots which would help this condition even in semikilled grades. Slivers, trying to control himself, remarks that there is too much difference in transverse and longitudinal properties to lighten the gage and if the thieves who make the plates would scrap the mills the Indians put in and cross roll the slabs maybe he could get by with thinner stuff.

Murphy and Shultz who are remaining outwardly indifferent but obviously following the situation closely seem to prefer to let matters take their course until they have ample reason to enforce their authority. From the gestures Rudy is making he is not in exact agreement and is pressing the officers for removal of the bodies before an explosion makes this feature unnecessary and of doubtful value. I am alternately between dish-rag and violin-string consistency and feverishly wish I'd never succumbed to the lure of hot pizza in the first place.

But to get back to the reasons for my discomfort, they are in somewhat controlled firm tones telling each other what they think of the manner in which plates are tested and Slivers most of all is denouncing the secrecy of the mill's tests and doubts if they ever take any. The Skull says he can't see what difference it makes with Slivers hell-for-strong-design and that test reports would only confuse him as the mill would have to send out one of their metallurgists to explain yield point. Murphy and Shultz clear for action at this remark, but Slivers who is watching in the mirror savagely bites off the end of a stogie instead of saying anything out loud.

My constitution has reached its endurance limit and only my basic trait of survival propels me to my feet which brings my eyes to where I can just see over Slivers' head and the door through which I so yearn to pass.

As I stand there hesitating my course of action, through the door comes a very frail Judy of about forty-odd who on spying Slivers just stands there jiggling some automobile keys and looks straight at him with that "wait till I get you home" connotation. Slivers sees her; his shoulders suddenly sag. He gathers his change and shuffles to the door, eyes to the floor, where the Judy takes over with an invisible leach.

The Skull smiles broadly at this not-so-happy ending for Slivers, and the riot squad starts to leave but I spot them twenty yards and beat them to it.

Prediction of Drawing Properties From Tensile Tests

*By E. N. LUDINGTON**

The load required to draw cylindrical cups and the maximum reduction possible can be predicted quite accurately from the ultimate tensile properties of the original sheet. (G 4)

When cylindrical cups are drawn from circular blanks, the force required is proportional to the original diameter of the blank. The maximum blank diameter and the maximum drawing force are in turn related to the tensile strength of the alloy being drawn. The relationship has been determined for a number of different materials and, in each instance, the maximum load was found to be proportional to the product of cup diameter multiplied by the tensile strength and the metal thickness.

Since the reduction in drawing is often much less than the maximum limits of drawability, the determination of the force required for intermediate drawing reductions should also be useful. Study of a number of different alloys indicates that a simple relationship exists between tensile strength and the force required for cupping and it seems to be almost independent of alloy composition.

The materials which were studied include commercially pure titanium, aluminum alloy 3004 (4 S), 70-30 brass, copper and Type 202 stainless steel. The mechanical properties of the alloys are shown in Table I.

The equipment used for drawing the cups is a 50,000-lb. capacity Riehle testing machine modified with a traveling head as shown in Fig. 1. An air cylinder is suspended from the head upon which a blank holder is positioned. Vertical travel of the ram permits a variation of hold-down pressure from 0 to 90 psi. on the blank. Within the blankholder and through the air cylinder a suitable punch and mandrel is placed in alignment with the die. The mandrel may be secured to the base of the testing machine as withdrawing or stripping needs dictate. As the head of the testing machine moves downward, the blank is formed into a cup and is removed through the exit in the top.

The die used for the tests was 1.500 in. in

*Group Leader, Special Products Section, Bridgeport Brass Co., Bridgeport, Conn.

Table I – Mechanical Properties of Alloys Used in Cupping Investigation

Material	Gage	Tensile Strength	Yield Strength	Elongation in 2 in.
Aluminum alloy 3004	0.036 in.	25,300 psi.	11,000 psi.	20.3%
70-30 brass No. 1	0.035	51,600	19,900	49.5
No. 2	0.036	47,700	16,100	65.0
No. 3	0.035	51,800	21,900	52.0
Copper	0.034	33,600	11,000	41.3
Titanium alloy Ti-55 A	0.036	72,800	55,300	28.8
Titanium alloy RC-70	0.041	120,800	91,400	20.0
Stainless steel Type 202	0.036	107,200	56,400	53.5

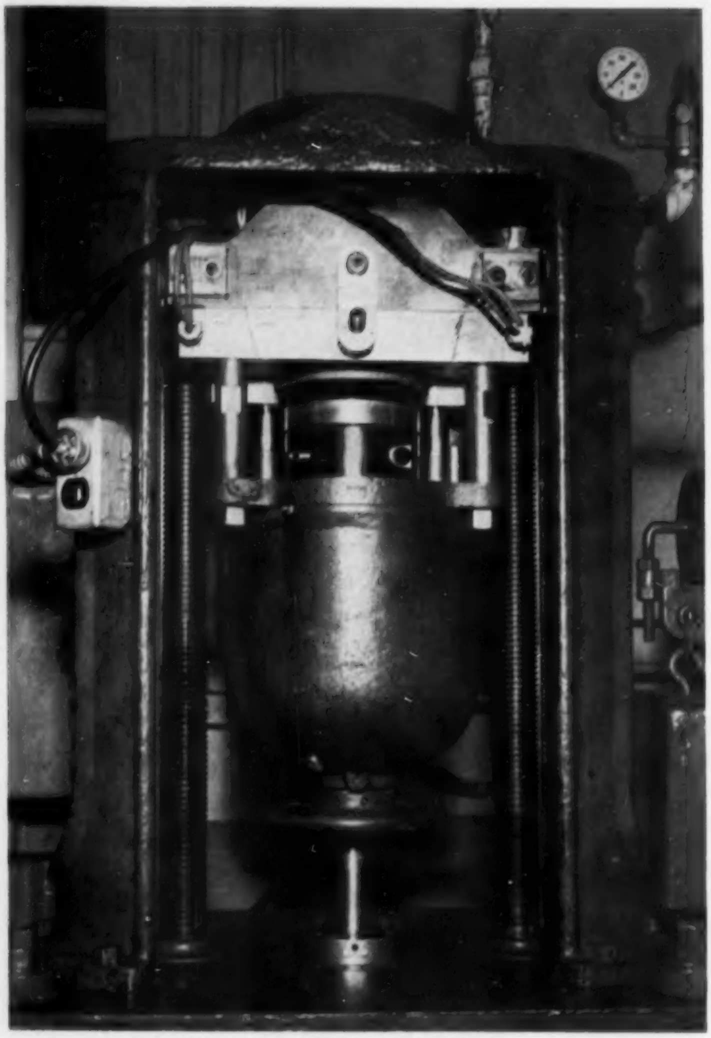


Fig. 1 – Equipment Used for Drawing Cups

diameter with a 3/16-in. entrant radius. To prevent ironing, a 1.400-in. diameter punch with a ¼-in. radius was employed.

For each of the sheets a series of blanks was cut ranging in diameter from 2.050 to 3.010 in. The blanks were cupped at a head speed of 2¾ in. per min. using Tycol-Angrove 25 sperm oil as a lubricant for the stainless steel and Whitfield-Richards 10 S lubricant for the other materials. The maximum load required to make the cup as a function of percent reduction for each of the materials is shown in Fig. 2.

Each alloy has a separate drawing curve, with a straightline relationship between percent reduction of the cup and the load required to form it. If the load for a given percent reduction is divided by the cross-section area of the cup, using original gage and die diameter as cup gage and cup outer diameter, and if the resulting cupping stress is in turn divided by the ultimate tensile strength of the material, a factor, N, is obtained which involves all of the variables. If this factor, N, is plotted against percent reduction by cupping, a simple relationship that seems to be independent of material results, as in Fig. 3.

Some "N" values calculated from data obtained by other investigators for zirconium are also included in Fig. 3. The cups, made from arc-melted sponge zirconium strip, were prepared using a 2.750-in. diameter die for the value at 30% reduction; a 1.950-in. die at 45% reduction and a 1.500-in. die at 50% reduction. All three

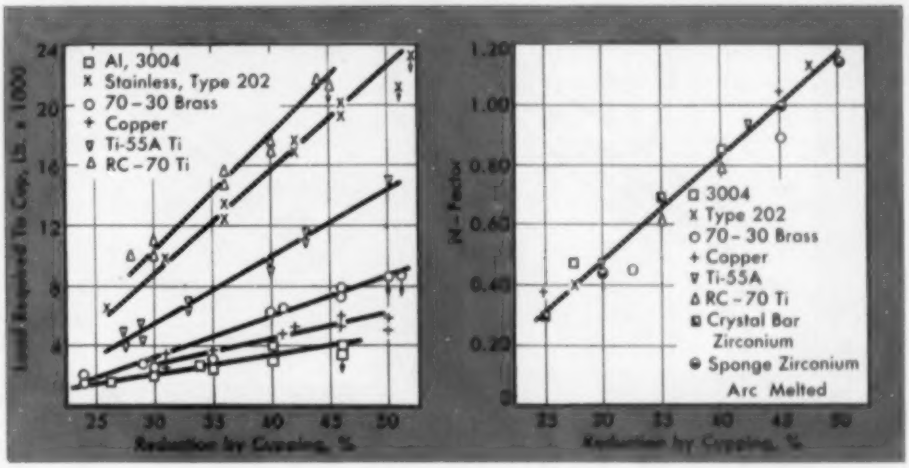


Fig. 2 (Left) – Load Required to Draw Various Alloys. Fig. 3 (Right) – Relation Between N-Factor and Drawing Reduction

dies had a 3/16-in. radius. The thickness of the disk cupped 30% was 0.021 in.; the other two were 0.042 in. thick. The crystal bar zirconium strip was cupped using a 1.500-in. diameter die with a 3/16-in. radius. With the possible exception of the 70-30 brass, all the materials tested have very similar cupping characteristics. Since

$$N = L \div AS$$

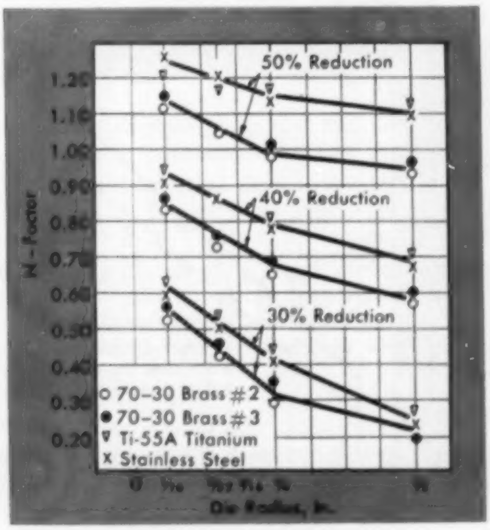
where L is cupping load; A, cross-section area of the cup; and S, the ultimate tensile strength; then

$$L = \pi t S (d - t) N$$

where t is metal thickness and d is die diameter.

To determine the effect on the general curve of changing the die radius, four dies were prepared with radii of 1/16, 5/32, ¼ and ½ in. The die diameters and the punch were the same as previously used. Blanks were cut from the stainless steel sheet and from the Ti-55 A titanium sheet previously used and from two different 70-30 brass sheets.

Fig. 4 – Effect of Die Radius on N-Factor



The effect of change in die radius is shown in Fig. 4. There is a noticeable difference between the N values obtained for the two brass sheets and those found for the stainless steel and the titanium. The effect of the die radius is found to be linear between 1/16 and ¼ in., with somewhat decreasing slope as the reduction is increased. The effect of increasing die radius from ¼ to ½ in. is much less than increasing from 1/16 to ¼ in.

The relationships between percent reduction, die radius and N value are shown differently in Fig. 5, and include the interpolated curves for a die with a 3/16-in. radius. The interpolated curves coincide almost exactly with the experimentally determined values.

It was of interest to know whether the results obtained in this investigation could be verified by other published data from which the factor, N, could be calculated. Two such reports appear to confirm the relationship. In the November 1950 issue of *Sheet Metal Industries*, Claude Arbel describes an investigation of the drawing properties of two aluminum alloys, 3003-O (3 S-O) and 5052-O (52 S-O), 18-8 Cr-Ni stainless steel and 65-35 brass. They were cupped using a 1.557-in. die which had a ¼-in. radius. H. W. Swift, in a symposium on deep drawing

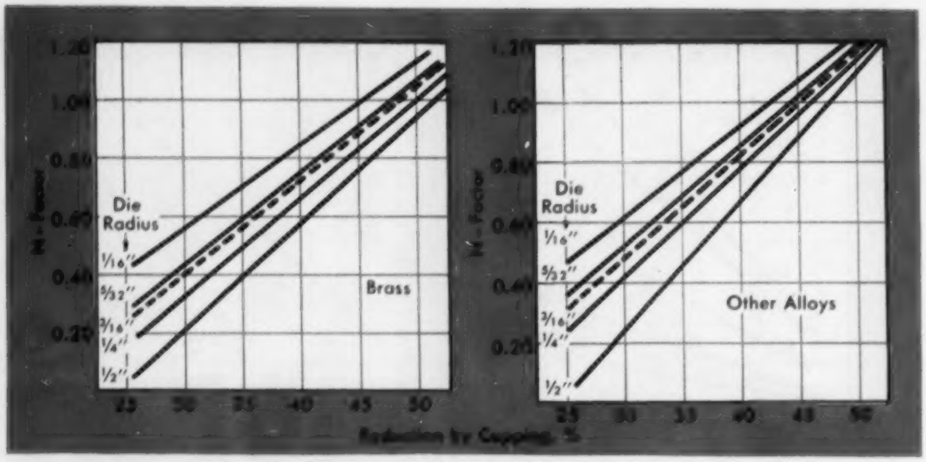


Fig. 5 – The N-Factor for Brass Differs From That of All Other Alloys Studied

conducted by the Institution of Automobile Engineers in 1940, reported some data on the cupping of 70-30 brass and aluminum bronze, using a die slightly more than 2 in. in diameter with a ¼-in. radius. Their results are shown in Fig. 6 with the curves for a ¼-in. radius die. Except at reductions below about 30%, the agreement is very good. Even below that figure the difference is not great.

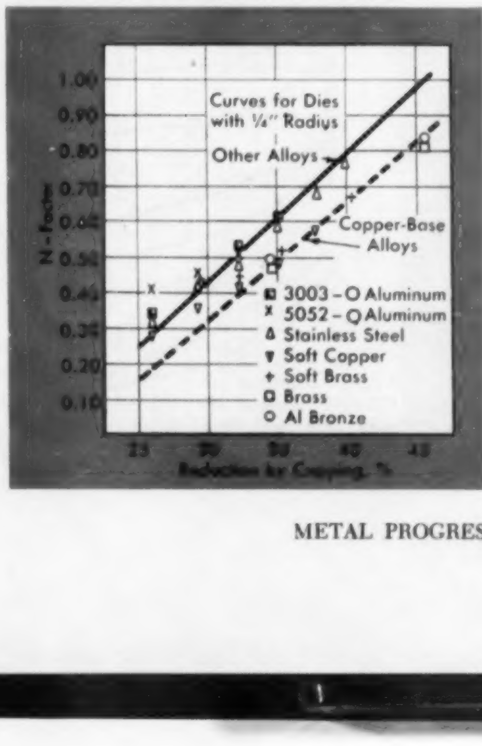
Although it may not be apparent, the maximum value of N is usually greater than 1.0, which means that the maximum stress on the sidewall of the cup is higher than the normal ultimate tensile strength of the material. The probable reason is the bi-axial stress system of cup forming. If a tensile specimen is constrained so that it cannot contract while it is being tested, an apparent tensile strength is found which is about 15% higher than normal.

If an N value of 1.10 is taken as a practical maximum, there exists a criterion for judging the maximum percent reduction by cupping which can be achieved. At reductions close to the maximum, the die radius effect is less than at lower reductions. For the copper-base alloys, an increase in die radius from 1/16 to ½ in. increases the maximum reduction from 49 to almost 55%. For other alloys the same change in radius extends the maximum reduction only from about 46 to 50%.

Although the relationship between tool radius and metal thickness has not been covered, the fact that Arbel's work on 0.125-in. sheet correlates quite well with this study indicates that thickness may not be an important factor.

Most of the basic conclusions to be obtained from this study are not new. The straightline relationship between load and percent reduction has been noted by many investigators. Similar equations for maximum cupping load, taking into account tensile strength, material thickness and cup diameter, have been developed by various authorities and applied to several quite different materials. The fact that die radii affect cupping loads is also not new. However, it is interesting to find that the cupping properties of unusual materials like zirconium and copper are very similar to those of the more common alloys. Because of this similarity it is possible to calculate cupping loads for many quite different materials easily with only two sets of curves of N versus percent reduction by cupping.

Fig. 6 – Cupping Tests by Other Investigators Confirm the Relationship Between Tensile Properties and Drawability



Heat Treatment of Welded Alloy Steels

British Welding Journal, February, 1956
Recommendation of Commission X, International Institute of Welding

													18-8 Cr-Ni	
A	Type of steel		1.2 Mn	0.5 Mo	0.5 Mo 0.25 V	1 Cr 0.5 Mo	2.25 Cr 1 Mo	3 Cr 0.5 Mo 0.5V	5 Cr 0.5 Mo	7 Cr 0.5 Mo	9 Cr 1 Mo	13 Cr	17 Cr	Not Stabilized	Stabilized
	A. S. T. M. Designation		A299	A204		A301 Grade B	A387 Grade D		A 357	A213 Grade T7	A213 Grade T9	A 240 Grade A	A 240 Grade D	Type 302*	Type 316*, 321* or 347*
B	Typical analysis, %	C	~0.20	max. 0.20	max. 0.15	max. 0.15	max. 0.15	~0.20	max. 0.15	max. 0.15	max. 0.15	max. 0.15	max. 0.1	0.08-0.12	0.05-0.08
		Mn	1.2	0.6	0.6	0.6	0.6	0.6	0.6	0.5	0.5	0.6			
		Si	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.7	0.7	0.4			
		Cr				1	2-2.5	3	4-6	6-8	8-10	11-13	17	17-20	17-20
		Ni												8-10	8-11
		V			0.2			0.5							
		Mo		0.5	0.5	0.5	1	0.5	0.5	0.5	1				2-3†
C	Examples of application, °F.		Pipe work and pressure vessels for temperatures up to					Pressure vessels containing hydrogen up to 900 °F.	Pipe work and vessels for temperatures up to			Tubes			
			885°	925°	975°	1025°	1065°		1200°	1250°	1300°				
			Turbine parts and chemical plant						Chemical plant		Turbine parts and chemical plant				
														Nonmagnetic parts	
D	Section ‡		Up to 5 in.				Up to 3 in.			Up to 3 in.					
E	Stress relief temperature, °F.		975-1200	1100-1300	1200-1300	1150-1350	1200-1375	1200-1375	1250-1375	1300-1375	1350-1425	1375-1475	1375-1475	No stress relief	750-1650
	Time, min. per in. (not less than 30)		Up to 125				Up to 100		Up to 75			Up to 50	Up to 50		
	Heating, °F./min.		6	6	6	6	4.5	4.5	3	3	Slow	Slow	Slow		1.5
	Cooling, °F./min.		3	3	3	3	3	3	3	3	Slow	Slow	Slow		Slow
						Preferably immediately after welding before cooling down									
F	Technical benefits from treatment E (besides stress relief and dimensional stability)			Tempering of heat affected zone and weld deposit											
G	Preheating for thicker sections, °F.		400-750	200-400	400-575	400-575	400-575	400-575	400-575	400-575	400-660	400-750			
H	Other heat treatment			Normalization is often specified: Heating to 1650-1750 °F. followed by annealing treatment E				1830° F. to 1885° F., followed by annealing treatment E				Two-stage: Heat to about 1825° F., Oil cool; Heat to about 1300° F., cool in still air		Cool rapidly from 1825 to 2000 °F.	Cool rapidly from 1825 to 2000 °F.
J	Scope of treatment H			Grain refining								Better corrosion resistance and grain refining		Better corrosion resistance (omitting intercrystalline corrosion)	Best resistance only necessary in very severe environments.

*A. I. S. I. type numbers ‡These dimensions are typical for certain applications but are not to be taken as limiting dimensions.

†Type 316 contains 2 to 3 % Mo, Type 321 contains Ti = 5 x %C; Type 347 contains Cb = 10 x % C

HOW SINGER GETS NEEDLE-FINE CONTROL OF CASE DEPTH WITH

AEROCARB® E+W

CARBURIZING COMPOUNDS

The Singer Manufacturing Company, Elizabethport, N. J., finds that AEROCARB E and W Carburizing Baths make it easy to control case depths of their sewing machine parts within thousandths of an inch, producing excellent wear resistance.

Vertical operating presser bar shafts and needle bar shafts for their 99 Class Sewing Machines are case-hardened at 1650°F. SINGER gets fast penetration with minimum distortion, and finds water-soluble AEROCARB E & W easy to remove. Parts emerge from the carburizing operation bright, clean and straight, ready for fast and easy finishing.

AEROCARB E & W can help you, too, get exactly the desired case composition and case depth with low distortion. For specific information on the use of Cyanamid's AEROCARB Carburizing Compounds, mail us the coupon.

CYANAMID'S HEAT TREATING COMPOUNDS INCLUDE:

AEROCASE® Case Hardening Compounds	AEROMET® Metallurgical Additive
AEROCARB® Carburizing Compounds	Metallic Stearates
AEROHEAT® Heat Treating Compounds	Surface Active Agents

Acids and other Heavy Chemicals

CYANAMID

AMERICAN CYANAMID COMPANY
METAL CHEMICALS SECTION
30 Rockefeller Plaza, New York 20, N. Y.

Send Technical Data Sheet on AEROCARB E & W Carburizing Compounds.

Name ....

Company ....

Address ....

City .... Zone .... State ....

MP8

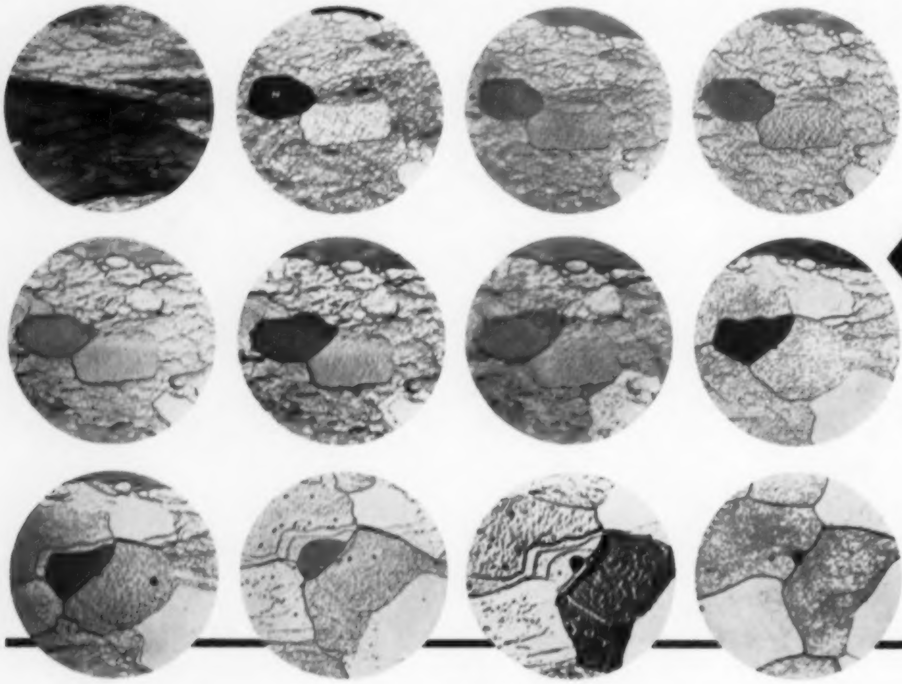
In Canada: North American Cyanamid Limited, Toronto and Montreal

Bausch & Lomb salutes...

William C. Coons

—Blue Ribbon Award Winner, A.S.M. Metallographic Exhibit

BLUE RIBBON AWARD WINNER for best photomicrograph in its class—Mr. William C. Coons, Chief Metallographer, Climax Molybdenum Co. of Michigan, Detroit, Michigan.



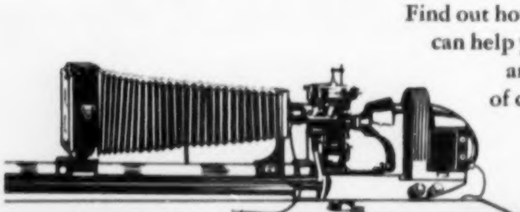
HIS AWARD-WINNING PHOTOMICROGRAPHS,

MADE WITH A BAUSCH & LOMB METALLOGRAPH— "Recrystallization of Wrought Molybdenum."

Bausch & Lomb Metallographs help industry boost output and maintain quality by providing detailed magnified images—visual or photographic—for routine work and advanced research.

The B&L Research Metallograph is one of a complete line of metallographic equipments. It provides ready choice of four different views of the same sample—by bright field, dark field, polarized light, or phase contrast—ensuring complete identification.

Find out how these faster, easier, completely dependable analyses can help you save on time and materials. Write for Catalog E-240, and for complete expert advisory service. No obligation, of course. Bausch & Lomb Optical Co., 63808 St. Paul St., Rochester 2, New York.



America's only complete optical source . . . from glass to finished product.

BAUSCH & LOMB

SINCE 1853

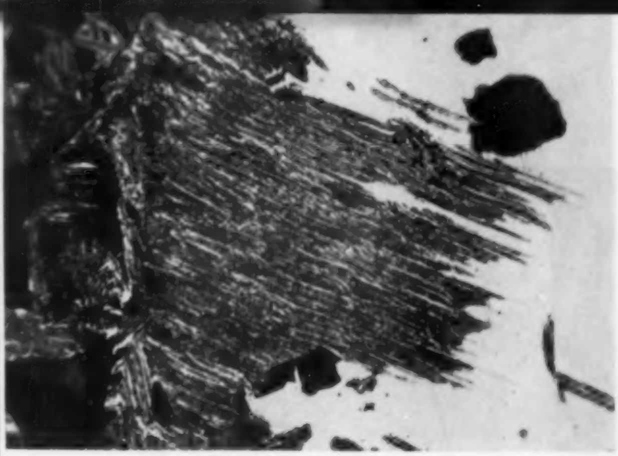


Fig. 1 – Bainite Formed in a Eutectoid Steel at 1000° F.†

The Bainite Transformation

*By R. F. HEHEMANN and A. R. TROIANO**

Published information (sometimes contradictory) about this solid-state reaction and the resulting metastable phase has been critically reviewed and assessed in the light of recent findings by the authors. (N 8, ST)

THE TERM BAINITE, proposed in honor of E. C. Bain, refers to the microstructural constituent in steel resulting from austenite transformation at intermediate subcritical temperatures. This transformation product, identified first in isothermal studies of austenite transformation[1] in a eutectoid steel, was characterized as an aggregate of ferrite and cementite having the feathery appearance illustrated in Fig. 1. Examination of bainite formed in other steels and at other transformation temperatures disclosed that its appearance could vary through wide ranges. Thus, microstructural appearance alone does not define this transformation adequately but (as will be shown later) the kinetic features of the transformation of austenite to bainite represent its most definitive characteristics.

It is the purpose of this article to describe the characteristics of the bainite transformation and to illustrate the points of similarity between it and the more conventional diffusion controlled (pearlite) and non-diffusion controlled (martensite) modes of decomposition.

Characteristics of Bainite

The principal characteristics of the bainite reaction are:

1. Transformation can take place at constant temperature[1] or during continuous cooling at appropriate rates. The progress of the isothermal reaction is illustrated in Fig. 2, and the general form of this curve is similar to that for typical nucleation-and-growth processes such as the eutectoid reaction. Thus, transformation begins after an induction period (time A in Fig. 2), proceeds for a short time and then halts. When reaction data of this sort at several temperatures are combined in the familiar TTT-diagram, the curve joining points representing the beginning of transformation has the shape of a capital C. In this respect, the transformation of austenite to bainite is similar to that of austenite to pearlite; however, significant differences between the two reactions prevent extension of this analogy. Note particularly that, in contrast to the pearlite reaction, decomposition of austenite to bainite need not result in *complete* disappearance of the austenite – that is, distance B in Fig. 2 may be less than 100%.

2. Time-temperature conditions under which austenite will transform to bainite either may overlap with those for the pearlite reaction or may be more or less separated depending on the alloy content of the steel. This is responsible for the wide variety of TTT-diagrams appearing in the literature[2-4]. The two extremes of this behavior are noted in Fig. 3. Complete overlapping

*Dr. Hehemann is Associate Professor and Dr. Troiano is Professor and Head of the Department of Metallurgical Engineering, Case Institute of Technology, Cleveland. The authors wish to express their appreciation to the Office of Naval Research, U.S. Navy, for support of this research and for permission to publish this survey.

†From "On Naming the Aggregate Constituents in Steel", by J. R. Vilella, G. E. Guellich and E. C. Bain, *Transactions*, A.S.M., Vol. 24, 1936, p. 225.

of the pearlite and bainite reactions (Fig. 3, left) gives the appearance of a single C-curve for decomposition in the entire transformation range between A_1 and the M_s temperature. This behavior is characteristic of plain carbon steels. Alloying elements, which affect the rates of the pearlite and bainite reactions differently, produce a more or less complete separation of the two C-curves as shown in Fig. 3 at right. The degree of separation depends on the amount and type of alloying element present.

3. The extent to which austenite will transform to bainite is a function of reaction temperature. As noted in Fig. 2, austenite partially transforms to bainite relatively rapidly once it has started, whereafter this transformation stops.[4,10,17] The influence of reaction temperature on the *extent* of this change from austenite to bainite, shown in Fig. 4, exhibits a striking similarity to the "M-T curve" showing the corresponding relationships for the martensite transformation. The fact that plain carbon and low-alloy steels do not exhibit this characteristic we believe[11,17] is due to the intervention of other transformations which may occur at temperatures near the top of the bainite range (see Fig. 3, left). In such instances it is difficult to recognize the incomplete nature of the bainite reaction, since the austenite no longer remains untransformed.

4. The bainite transformation is relatively insensitive to the prior austenite grain size;[2,4] however, recent studies[3] indicate that austenitizing temperature, in certain steels, may exert a role beyond that attributable to changes in grain size or to homogenization. For example, the reaction may be accelerated after a high austenitizing temperature. This phenomenon is reversible in the sense that the *rate* of the bainite reaction returns toward its normal value when the cooling of the sample from a high austenitizing temperature is interrupted at a lower temperature in the austenite range.

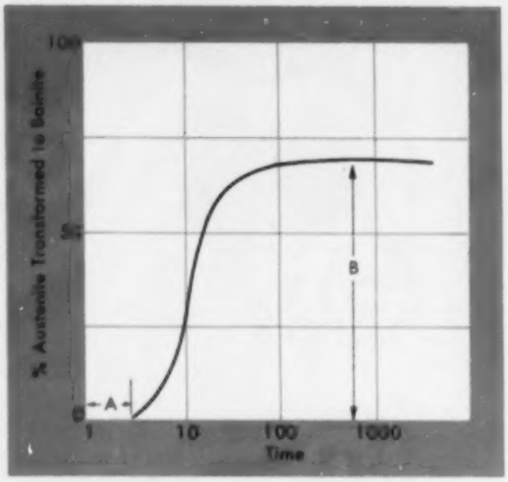


Fig. 2—Progress of the Isothermal Bainite Reaction (Schematic)

5. When no other reaction (austenite to pearlite, ferrite or cementite) overlaps the bainite reaction in time and temperature, the austenite not transformed to bainite is extremely persistent and remains untransformed for exceptionally long times at the transformation temperature. It has been suggested[5] that the rapid reaction to bainite does not stop completely but continues at a greatly reduced rate. However, quantitative metallographic studies[23] made at Case Institute on a medium-alloy hypo-eutectoid steel have shown no observable increase in the amount of transformation product throughout the time interval from 3 to 280 hr. In this instance, at least, the bainite reaction had stopped completely.

In view of the relatively high temperatures at which the reaction remains incomplete (700 to 1000° F.), eventual disappearance of the austenite must be anticipated; however, the reaction sequence may become extremely complex. For

1. "Transformation of Austenite at Constant Subcritical Temperatures", by E. S. Davenport and E. C. Bain, *Transactions* of the American Institute of Mining and Metallurgical Engineers, Vol. 90, 1930, p. 117.

2. "Influence of Austenite Grain Size Upon Isothermal Transformation Behavior of S.A.E. 4140 Steel", by E. S. Davenport, R. A. Grange and R. J. Hafsten, *Transactions* of the American Institute of Mining and Metallurgical Engineers, Vol. 145, 1941, p. 301.

3. "Effects of High Temperature Heating on the Isothermal Formation of Bainite", by S. A. Cottrell and T. Ko, *Journal* of the Iron and Steel Institute, Vol. 173, 1953, p. 224.

4. "The Intermediate Transformation in Alloy Steels", by W. T. Griffiths, L. B. Pfeil and N. P. Allen, Second Report, Alloy Steels Research Committee, Iron and Steel Institute, 1939, p. 343.

5. "Quantitative Study of Austenite Transformation", by R. A. Flinn, E. Cook and J. A. Fellows, *Transactions*, American Society for Metals, Vol. 31, 1943, p. 41.

6. "Influence of Carbon Content Upon the Transformation in 3% Chromium Steels", by T. Lyman and A. R. Troiano, *Transactions* of the American Society for Metals, Vol. 37, 1946, p. 402.

7. "Isothermal Transformation of Austenite in 1% Carbon, High-Chromium Steels", by T. Lyman and A. R. Troiano, *Transactions* of the American Institute of Mining and Metallurgical Engineers, Vol. 162, 1945, p. 196.

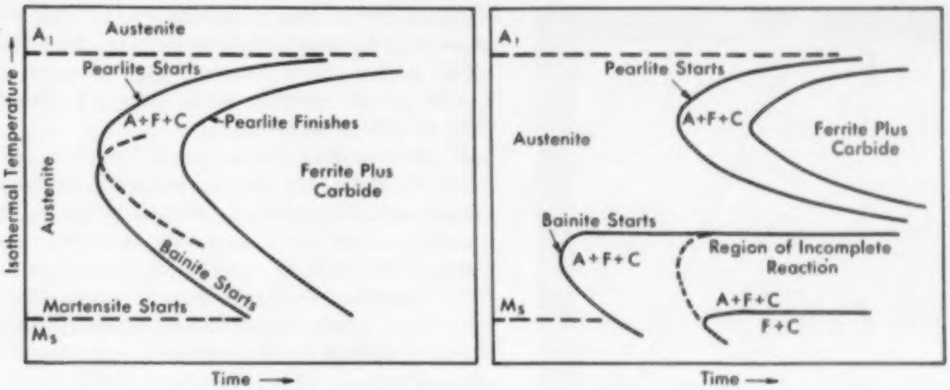


Fig. 3 – Left: Pearlite and Bainite Reactions Overlap, as in Plain Carbon Steel. Right: The reactions are separated, as in high-alloy steel

example, in highly alloyed chromium or nickel steels this is acomplished by the nucleation and growth of individual ferrite and cementite plates.[6, 7, 11]

6. A definite temperature exists above which austenite will not transform to bainite.[6, 7] This temperature, which has been designated B_s, is determined experimentally by the intersection of the curve in Fig. 4 with the horizontal axis of coordinates. Like M_s, the actual B_s temperature is dictated by the composition of the austenite. Addition of carbon and all of the common alloying elements will lower B_s and reduce the rate of transformation.[19, 20, 21] Substitutional alloying elements are less effective than carbon by approximately one order of magnitude, and stand in the order: manganese, chromium, nickel and molybdenum. Qualitatively, the behavior of the individual elements appears to parallel their influence on the M_s temperature.

7. It is possible to transform all of the martensite to bainite, isothermally, below a certain limiting temperature (Fig 4). This temperature is designated B_f.

The relationship between composition and B_f temperature has seldom been recognized. Studies of Krupp-type carburizing steels[25] and 3% chromium steels[6] indicate that this temperature is relatively insensitive to carbon content. We find in studies at Case Institute of Technology that it is also insensitive to content of nickel, chromium and molybdenum in various combinations – at least for a wide variety of medium alloy steels – and falls within a relatively narrow temperature range, around 600 to 700° F. (In many published TTT-diagrams for medium-alloy steels, complete transformation is attained at temperatures well above 700° F. In these instances, however, the pearlite and bainite reactions overlap, and transformation to pearlite may account for the high B_f.) The temperature range of incomplete austenite decomposition is narrower in the higher carbon and alloyed steels,

8. "The Bainite Reaction in Hypo-Eutectoid Steels", by E. P. Klier and T. Lyman, *Transactions* of the American Institute of Mining and Metallurgical Engineers, Vol. 158, 1944, p. 394.

9. "On the Progress of Austenite Decomposition in the Supercooled State in Iron-Nickel-Carbon Alloys", by H. Lange and K. Mathieu, *Mitteilungen aus dem Kaiser-Wilhelm-Institut für Eisenforschung,* Vol. 20, 1938, p. 125.

10. "On the Transformations in Manganese Steels", by F. Wever and K. Mathieu, *Mitteilungen aus dem Kaiser-Wilhelm-Institut für Eisenforschung,* Vol. 22, 1940, p. 9.

11. "The Transformation Characteristics of Ten Selected Nickel Steels", by J. P. Sheehan, C. A. Julien and A. R. Troiano, *Transactions* of the American Society for Metals, Vol. 41, 1949, p. 1165.

12. "Decomposition of Austenite in High-Speed Steel at Constant Temperature", by A. Gulyaev, *Metallurg,* Vol. 15, 1940, p. 43.

13. "The Transformation of Austenite in High-Speed Steel", by S. Steinberg and V. Zyuzin, *Archiv für das Eisenhüttenwesen,* Vol. 7, 1934, p. 537.

14. "Study of the Transformation of Austenite in a Chromium Steel", by S. Steinberg and V. Zyuzin, *Revue de Metallurgie,* Vol. 31, 1934, p. 554.

15. "Kinetics of Austenite Decomposition in High-Speed Steel", by P. Gordon, M. Cohen and R. S. Rose, *Transactions* of the American Society for Metals, Vol. 31, 1943, p. 161.

16. "Austenite Transformation Above and Within the Martensite Range", by R. T. Howard and M. Cohen, *Transactions* of the American Institute of Mining and Metallurgical Engineers, Vol. 176, 1949, p. 384.

17. "The Transformation and Retention of Austenite in S.A.E. 5140, 2340 and T-1340 Steels of Comparable Hardenability", by A. R. Troiano, *Transactions* of the American Society for Metals, Vol. 41, 1949, p. 1093.

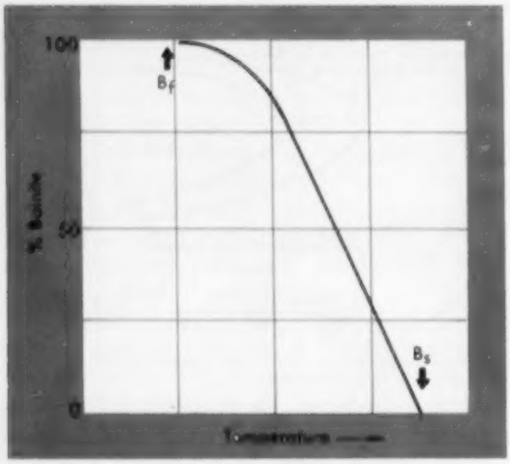


Fig. 4 – Influence of Reaction Temperature on the Amount of Bainite Formed in the Isothermal Reaction – the "B-T Curve" (Schematic)

since an increase in carbon and alloying elements depresses B_s without lowering B_f.

No relationship has been observed between the M_s and B_f temperatures. The latter may be either above or below, depending upon the analysis of the steel. In those compositions in which M_s is *above* B_f, it is impossible to produce a fully bainitic structure by any thermal treatments known to us. The full significance of this frequently has not been appreciated in commercial practice and undoubtedly has helped to further the concept that the mechanical properties of bainitic structures are inferior to those of tempered martensite.[26] In compositions for which M_s is *below* B_f, fully bainitic structures can be obtained. An increase of carbon content expands the temperature range between M_s and B_f because of its potent effect in lowering M_s. The higher carbon steels thus lend themselves more readily to heat treating cycles designed around fully bainitic structures.

8. Many studies (References 6, 7, 8, 10, 22, 24, 27 to 32) show that the carbide resulting from austenite decomposition in the bainite range (at least *above* 600° F.) is invariably cementite, regardless of the alloy content of the austenite. (This is orthorhombic carbide of composition $(Fe, M)_3C$ where M stands for various alloying elements. This is to be contrasted with complex alloy carbides or alloy-rich cementite which may occur at higher temperatures and with special transition carbides which may occur at lower temperatures.) The alloy content of this cementite in the bainite microconstituent follows that of the austenite – that is, there is no partition of alloying elements associated with the transformation. However, continued stay at the transformation temperature or tempering at higher temperatures will start a redistributing of the alloy between carbide and ferrite if equilibrium so demands.

The carbide in the bainite formed at temperatures *below* approximately 600° F. (as can occur in relatively high-carbon steels) is different from the cementite formed at higher temperatures. Magnetic measurements reveal no cementite Curie point[32, 33] and dilatometric measurements[34] produce total expansions which are larger than those predicted on the basis of a ferrite-plus-cementite structure.

9. It is also well established that partial transformation of austenite in the bainite range lowers

18. M. S. Thesis, by J. Collins, University of Notre Dame, 1948.

19. M. S. Thesis, by R. C. Hall, Case Institute of Technology, 1952.

20. "Isothermal Transformation Diagrams for Nickel Steels", *Metallurgia*, May 1951, p. 234, and June 1951, p. 280.

21. "Research on Isothermal Transformation of Austenite in France and Abroad", by G. Delbart and M. Ravery, *Revue de Metallurgie*, Vol. 46, 1949, p. 475.

22. "Isothermal Transformation of Austenite", by A. Hultgren, *Transactions* of the American Society for Metals, Vol. 39, 1947, p. 915.

23. B. S. Thesis, by C. A. Beiser, Case Institute of Technology, 1951.

24. "Isothermal Transformation of Austenite and Partitioning of Alloying Elements in Low-Alloy Steels", by A. Hultgren, *Kungliga Svenska Vetenskapsakademiens Handlingar*, Vol. 4, 1953, p. 3.

25. "Transformations in Krupp-Type Carburizing Steels", by A. R. Troiano and J. E. DeMoss, *Transactions* of the American Society for Metals, Vol. 39, 1947, p. 788.

26. "The Embrittlement of Alloys Steels at High Strength Levels", by L. J. Klingler, W. J. Barnett, R. P. Frohmberg and A. R. Troiano, *Transactions* of the American Society for Metals, Vol. 46, 1954, p. 1557.

27. "On the Process of Transformation in Chromium and Manganese Steels", by E. Houdremont, W. Koch and H. J. Wiester, *Archiv für das Eisenhüttenwesen*, Vol. 18, 1945, p. 147.

28. A. Hultgren, *Jerkontorets Annaler*, Vol. 135, 1951, p. 403.

29. "On the Transformation Behavior and Tempering Stability of Steel with Specific Carbide-Forming Elements, Represented in an Example of Vanadium Steel", by F. Wever, A. Rose and W. Peter, *Archiv für das Eisenhüttenwesen*, Vol. 21, 1950, p. 367.

30. "Carbides in Isothermally Transformed Chromium Steels", by W. Crafts and J. L. Lamont, *Transactions* of the American Institute of Mining and Metallurgical Engineers, Vol. 185, 1949, p. 957.

31. "New Contributions to the Knowledge of Carbides in Alloy Steels", by W. Koch and H. J. Wiester, *Stahl und Eisen*, Vol. 69, 1949, p. 73.

M_s of the untransformed austenite and increases the amount of austenite retained at room temperature. (See references 6 to 15, 17, 36.) This has been attributed by some[29, 37] to enrichment of the austenite in carbon. However, it has been observed[39, 40] that M_s can be lowered by holding the steel in the bainite transformation range for times shorter than that required for the formation of visible amounts of transformation product, and that high-purity, binary iron-chromium and iron-manganese alloys also retain greater amounts of austenite at room temperature after partial transformation at high temperatures.[6, 10] Thus, a true stabilization process also must be active in the bainite range, as pointed out by Troiano and Greninger in Ⓜ Metals Handbook.[41]

Carbon enrichment also has been postulated[38, 42] to explain the observation that complete transformation to bainite does not occur at temperatures near B_s. However, the existing metallurgical literature does not appear to support this possibility. Although lattice parameter measurements of retained austenite in steels containing 0.3 to 0.4% carbon have indicated carbon enrichment, studies with the electron microscope have demonstrated that this enrichment is highly localized around each bainite plate.[45] Futhermore, carbon enrichment has not been detected in hypereutectoid steels under conditions where large amounts of austenite remain untransformed.[7, 36, 46, 47] Thus, in both hypo-eutectoid and hypereutectoid steels, large regions of nonenriched austenite exist after the end of the bainite transformation. Although a localized carbon concentration gradient could stop the growth of a bainite plate, this hypothesis does not explain why new plates do not nucleate at some distance from the existing ones.

10. Structurally, bainite is an aggregate of ferrite and carbide. Although the microstructure may assume a variety of forms, all are more or less acicular, as shown typically in Fig. 5.

The morphology changes gradually with the reaction temperature, so no pronounced structural change is observed over any small temperature range. As is true of martensitic structures,[39] the appearance of bainite is dictated primarily by the temperature of formation rather than the composition of the austenite. At the top of the range, the structure resembles an acicular ferrite with a few carbide particles dispersed throughout the ferrite. (See micros for 970 and 900° F. in Fig. 5.) This structure has been termed the "X constituent" by Davenport[48] or "pro-bainitic ferrite" by Hultgren.[22] Carbide particles become

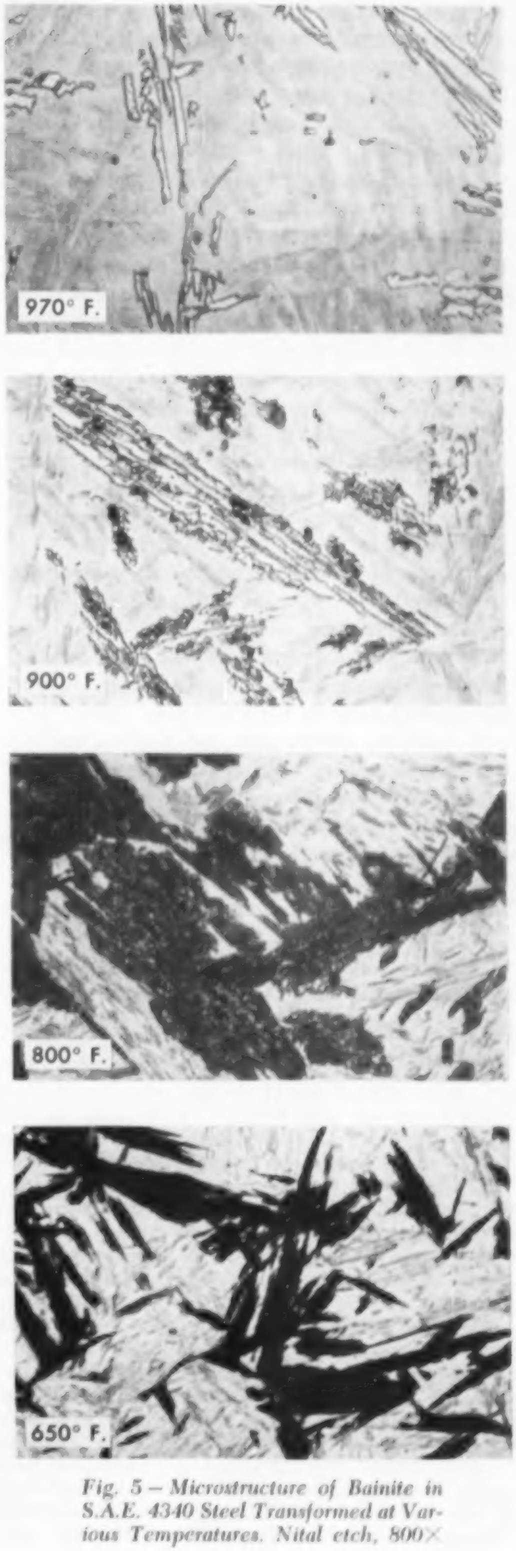


Fig. 5 – Microstructure of Bainite in S.A.E. 4340 Steel Transformed at Various Temperatures. Nital etch, 800×

more numerous and more finely dispersed and the acicularity becomes more pronounced as the reaction temperature is lowered. Figure 5 shows that at temperatures near M_s, the structure assumes the appearance of tempered martensite, although bainite plates are thinner than martensite plates formed at the same temperature.[16]

11. Surface distortion, similar to that observed in the martensite transformation, accompanies the decomposition of austenite to bainite,[50, 51] but a detailed analysis of the distortion producing the surface relief has not been made for bainite, as has been done for martensite. It has also been observed that bainite grows in a slow, continuous manner, quite in contrast to the almost instantaneous propagation of a martensite plate. For this reason it has been suggested[50] that the formation of bainite involves a shear transformation in which the rate of propagation is controlled by the diffusion of carbon.

The rate of growth of the bainitic constituent depends upon the reaction temperature and upon the composition of the austenite. The plates grow both in length and thickness; however, the growth in length is considerably faster. Quantitative measurements have not been reported.

12. Lattice relationship and the orientation habit in the austenite-bainite transformation depend upon the reaction temperature. The orientation habit of bainite in a plain carbon steel (0.92% C) was found to vary continuously with transformation temperature.[36] Basically, the habit plane does not delineate any low index plane of the austenite. The habit plane at 840° F. was approximately octahedral and varied along a [134] austenite zone as the transformation temperature was lowered.

In eutectoid steels, bainite formed at 840 and 750° F. displayed the Nishiyama lattice relationship between austenite and ferrite, whereas that formed at 680° F. exhibited the Kurdjumov and Sachs relationship.[52] These lattice relationships suggest that bainite is nucleated by ferrite.

Direct observation of the lattice relationship between austenite and the carbide phase of bainite has not been reported. Electron microscope studies[45, 53, 54] reveal that the carbide phase is present as small, parallel platelets preferentially oriented with respect to the needle axis. In bainite formed at low temperatures, the carbide plates are extremely fine and are aligned along planes in the ferrite matrix at an angle to the major axis of the bainite needle; at higher temperatures, the carbide particles are larger, and lie parallel to the major axis of the bainite plate.

13. Applied stress during transformation in the bainite range markedly accelerates the reaction rate.[55 to 58, 63] Furthermore – although the data are fragmentary – there are indications that the total amount of bainite may be increased and that some transformation may be induced at temperatures above B_s by tensile stresses. A general correlation between the influence of stress on the bainite and on the martensite transformations appears likely.

Stabilization of Bainite

Reaction kinetics in the bainite range depend upon prior thermal history. For example, the time required for the formation of 1% bainite (induction period) in hypo-eutectoid steels is shortened appreciably by a brief interruption in the pro-eutectoid ferrite range during quench-

32. "On Transformation Kinetics", by F. Wever and H. Lange, *Mitteilungen aus dem Kaiser-Wilhelm-Institut für Eisenforschung*, Vol. 14, 1932, p. 71.

33. "Structural Changes During the Tempering of High-Carbon Steels", by D. P. Antia, S. Fletcher and M. Cohen, *Transactions* of the American Society for Metals, Vol. 32, 1944, p. 290.

34. "The Determination of the Transformation Characteristics of Alloy Steels", by N. P. Allen, L. B. Pfeil and W. T. Griffiths, Second Report, Alloy Steels Research Committee, Iron and Steel Institute, 1939, p. 369.

35. "Electron-Diffraction Study of Iron Carbides in Bainite and Tempered Martensite", by A. E. Austin and C. M. Schwartz, American Society for Testing Materials Preprint No. 165, 1952.

36. "Crystallography of Austenite Decomposition", by A. B. Greninger and A. R. Troiano, *Transactions* of the American Institute of Mining and Metallurgical Engineers, Vol. 140, 1940, p. 307.

37. "Redistribution of Carbon During Transformation in Bainite Range", by L. M. Pevzner, G. M. Rovenski and T. D. Kubyschkina, *Doklady Akademii Nauk S.S.S.R.*, Vol. 85, 1952, p. 811.

38. "Kinetics of the Decomposition of Austenite", by C. Zener, *Transactions* of the American Institute of Mining and Metallurgical Engineers, Vol. 167, 1946, p. 550.

39. "Ar" in Chromium Steels", by E. P. Klier and A. R. Troiano, *Transactions* of the American Institute of Mining and Metallurgical Engineers, Vol. 162, 1945, p. 175.

40. "Thermal Stabilization of Austenite in Iron-Carbon-Nickel Alloys", by E. R. Morgan and T. Ko, *Acta Metallurgica*, Vol. 1, 1953, p. 36.

41. "The Martensite Transformation", by A. R. Troiano and A. B. Greninger, Metals Handbook, American Society for Metals, 1948, p. 263.

42. "On Transformation Kinetics", summarized by F. Wever, *Stahl und Eisen*, Vol. 69, 1952, p. 664. (A series of papers in *Mitteilungen aus dem Kaiser-Wilhelm-Institut für Eisenforschung*, 1930 to 1940.)

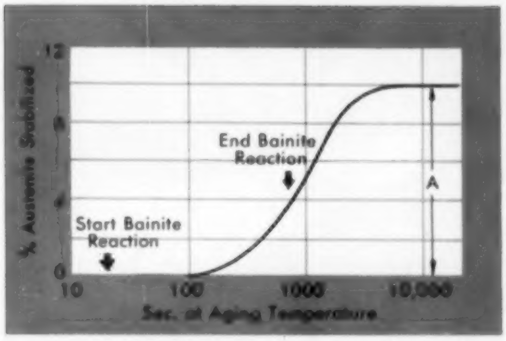


Fig. 6 – If Steel Is Held Isothermally in Bainite Zone Long Past the End of the Bainite Reaction, a Considerable Amount of the Untransformed Austenite Is Stabilized Against Transformation at Lower Temperatures[62]

ing.[59, 61] On the other hand, holding a hypereutectoid steel in the pro-eutectoid carbide range markedly delays the bainite transformation.[9, 60]

Decomposition at a low temperature in the bainite range is retarded by prior treatment at a higher temperature in this range.[9, 10, 60] The total volume of metal transformed at the lower temperature may also be reduced.[62] This reveals that the bainite reaction is susceptible to a stabilization similar to that for martensite.

Both the time and temperature of the prior treatment control the amount of austenite which becomes stabilized. See Fig. 6, wherein the times for the beginning and ending of the bainite reaction are designated by arrows. Significant amounts of stabilized austenite do not appear until the holding time approaches the end of the bainite reaction at the initial temperature – that is, until appreciable transformation has taken place. Continued isothermal treatment after the bainite reaction has stopped results in additional stabilization, as demonstrated in Fig. 6; however a plateau value is achieved eventually. These results suggest that this stabilization process is fundamental to the incomplete nature of the bainite reaction at the higher transformation temperatures.

The influence of isothermal temperature on the maximum amount of austenite which is stabilized against reaction at lower temperatures (distance A in Fig. 6) is revealed in Fig. 7. The amount of stabilized austenite appears to increase as the holding temperature is lowered; it passes through a maximum value and then decreases as the holding temperature approaches the reaction temperature.[62] As in the stabilization of the martensite reaction, the behavior results largely from the fact that the amount of austenite available for transformation at the lower temperature becomes less as the holding temperature is reduced (as is shown in Fig. 4).

Reaction Mechanism

The many suggestions for the mechanism of the bainite reaction may be classified in two basically different categories. One, contained in references 8, 38, 49 and 65, requires that bainite initially forms as supersaturated ferrite by a lattice shearing process. According to the other proposal due to Hultgren,[22] bainite forms directly from austenite as an aggregate of ferrite and cementite. Proponents of both mechanisms agree that the transformation is nucleated by ferrite rather than by cementite.

According to the first hypothesis (supersaturated ferrite mechanism), B_s represents that tem-

43. "Constitutional Research as a Basis for Heat Treatment of Steel", A. Rose and W. Peter, *Stahl und Eisen*, Vol. 72, 1952, p. 1063.
44. "Application of the Isothermal Transformation Diagram to the Normalizing of EN 40 C Steel", by J. A. Cameron, *Journal* of the Iron and Steel Institute, Vol. 170, 1952, p. 313.
45. "On the Question of the Adaptation of the Electron Microscope for the Structural Investigation of Steels", by A. Schrader and F. Wever, *Archiv für das Eisenhüttenwesen*, Vol. 23, 1952, p. 489.
46. "Stimulation of the Bainite Transformation in Steels by Small Amounts of Alpha Iron", by W. Jellinghaus, *Archiv für das Eisenhüttenwesen*, Vol. 12, 1952, p. 459.
47. V. Gridnev and G. Kurdjumov, *Teoriya i Praktika Metallurgii*, Vol. 8, 1936, p. 2.
48. "Isothermal Transformation in Steels", by E. S. Davenport, *Transactions* of the American Society for Metals, Vol. 27, 1939, p. 837.
49. "Structure of the Intermediate Range in Steel and Its Origin", by H. J. Wiester, *Archiv für das Eisenhüttenwesen*, Vol. 18, 1944, p. 97.
50. "The Formation of Bainite", by T. Ko and S. A. Cottrell, *Journal* of the Iron and Steel Institute, Vol. 172, 1952, p. 307.
51. "The Formation of Bainite in an EN 21 Steel", by T. Ko, *Journal* of the Iron and Steel Institute, Vol. 175, 1953, p. 16.
52. "Lattice Relationships in Decomposition of Austenite to Pearlite, Bainite and Martensite", by C. V. Smith and R. F. Mehl, *Transactions* of the American Institute of Mining and Metallurgical Engineers, Vol. 150, 1942, p. 211.
53. "Electron Microstructures of Bainite in Steel", American Society for Testing Materials *Bulletin*, May 1952, p. 62.
54. Report of Subcommittee XI, *Proceedings* of the American Society for Testing Materials, Vol. 52, 1952, p. 543.
55. "Tensile Properties of Unstable Austenite and Its Low-Temperature Decomposition Products", by A. H. Cottrell, *Journal* of the Iron and Steel Institute, Vol. 151, 1945, p. 93.

perature at which stress-free ferrite and austenite of identical composition are in equilibrium.[38, 65] Interpreted literally, this requires that, once nucleated, the mode of development of a bainite plate should be identical with that of a martensite plate. Although relief effects (surface distortions) have been observed[50] in the transformation of austenite to bainite, each plate developed in a slow, continuous manner. In the absence of rapid propagation of the new phase, the high diffusion rate of carbon in ferrite or austenite would prohibit the formation of supersaturated ferrite with the same composition as the parent austenite. Consequently, it has been suggested[50, 66] that growth of a bainite plate is controlled by diffusion of carbon through austenite. Statistical fluctuations in carbon concentration create small, low-carbon regions whose M_s is above the transformation temperature. (In high-carbon steels, these low-carbon regions may result from carbide precipitation which may precede or accompany the bainite transformation.) Consequently, these regions transform martensitically and continue to grow slowly as carbon is removed from the austenite-bainite interface. This migration of carbon may be accomplished by precipitation of a carbide phase or by diffusion into the surrounding austenite.

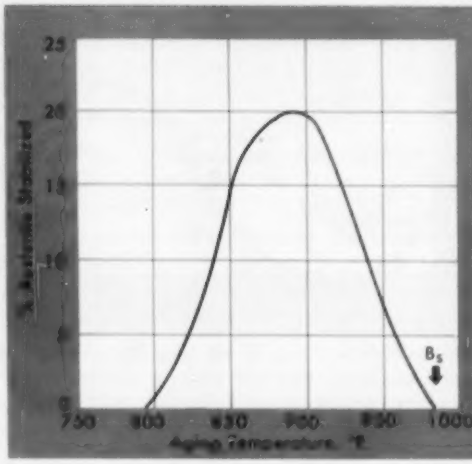


Fig. 7 – Amount of Austenite Stabilized Against Transformation at 800° F. Because of Long Isothermal Heating at Temperatures Above 800° F. (Reference 62)

Hultgren's mechanism, involving the separate precipitation of ferrite and cementite from austenite, is based on observations of the structure and composition of bainite. The transformation is considered to be nucleated by a special form of ferrite (termed para-ferrite) which inherits its alloy content from austenite while its carbon content corresponds to a special metastable equilibrium value dictated by the transformation temperature. Formation of this para-ferrite enriches the surrounding austenite in carbon so that cementite (with the alloy content of the austenite) forms in juxtaposition to the ferrite. The ferrite then continues its growth around the cementite particle. Electron micrographs confirm the structural features of this mechanism.[45]

Conclusion – It is apparent that the bainite transformation occupies a unique position in solid-state reactions. Although it exhibits most of the characteristics of a martensite transformation, the slow rate of propagation of individual plates indicates that diffusion controlled processes must have an important role in the mechanism of the bainite reaction.

56. "The Acceleration of the Rate of Isothermal Transformation of Austenite", by M. D. Jepson and F. C. Thompson, *Journal* of the Iron and Steel Institute, Vol. 162, 1949, p. 49.

57. "A Note on the Physical Properties of an Austenite Weld-Metal and Its Structural Transformations on Straining", by K. Winterton, *Journal* of the Iron and Steel Institute, Vol. 151, 1945, p. 87.

58. "Some Characteristics of the Metastable Austenite of 4 to 6% Chromium Plus ½% Molybdenum Cast Steel", by G. J. Guarnieri and J. J. Kanter, *Transactions* of the American Society for Metals, Vol. 40, 1948, p. 1147.

59. "Anisothermal Decomposition of Austenite", by J. H. Hollomon, L. D. Jaffe and M. R. Norton, *Transactions* of the American Institute of Mining and Metallurgical Engineers, Vol. 167, 1946, p. 419.

60. "Anisothermal Formation of Bainite and Pro-Eutectoid Constituents in Steels", by L. D. Jaffe, *Transactions* of the American Institute of Mining and Metallurgical Engineers, Vol. 176, 1948, p. 363.

61. "Relationship Between Transformation at Constant Temperature and Transformation During Cooling", by G. K. Manning and C. H. Lorig, *Transactions* of the American Institute of Mining and Metallurgical Engineers, Vol. 167, 1946, p. 442.

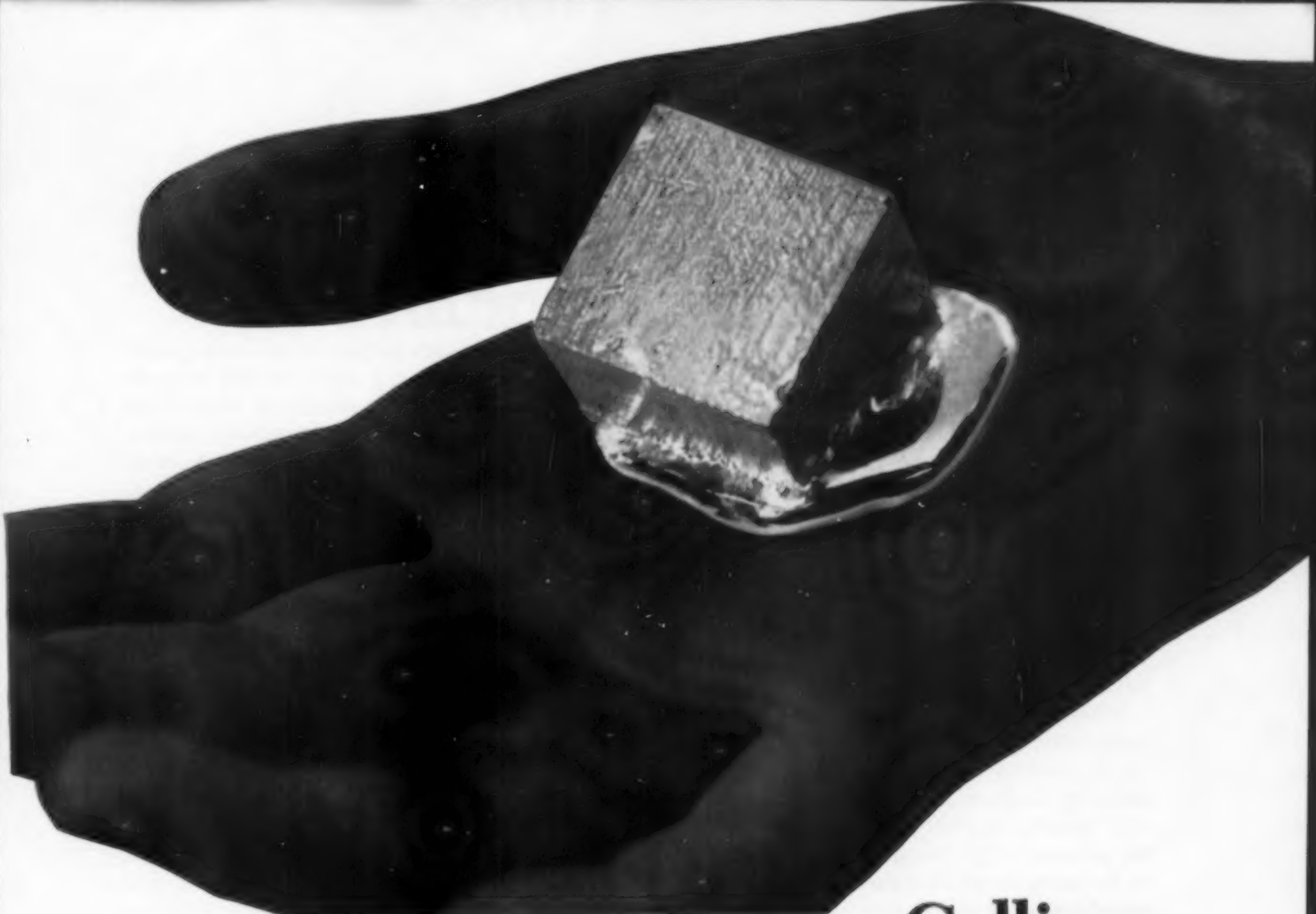
62. "Stabilization of the Bainite Reaction", by R. F. Hehemann and A. R. Troiano, *Transactions* of the American Institute of Mining and Metallurgical Engineers, Vol. 200, 1954, p. 1272.

63. "Isothermal Transformation of Austenite Under Externally Applied Tensile Stress," by S. Bhattacharyya and G. L. Kehl, *Transactions* of the American Society for Metals, Vol. 47, 1955, p. 351.

64. Atlas of Transformation Diagrams, U. S. Steel Corp., 1953.

65. "Eutectoid Decompositions", by J. C. Fisher, Thermodynamics in Physical Metallurgy, American Society for Metals, 1950, p. 201.

66. "Calorimetric Investigation of a Bainite Transformation", by Krisement and Wever, *Archiv für das Eisenhüttenwesen*, Vol. 25, 1954, p. 489.



Gallium

*By H. P. BONEBRAKE**

Gallium, which will melt in the hand, does not boil until it reaches 3600° F. This characteristic is one of its most useful properties. (Ga)

A RECENT discovery by the laboratory staff of the refining division at the East St. Louis works of Aluminum Co. of America, of a new use for gallium brings again to attention a long-available but little-used metal. The liquid metal is an effective sealant for glass joints and valves in vacuum equipment. It has more than doubled the operating time of a ground glass joint and points the way to simplification and lower costs. But this novel application does not quite approach the wide commercial use long sought by gallium's producers.

Discovered and named in 1875 by Lecoq de Boisbaudran, gallium's existence and strange physical and chemical properties were predicted six years earlier by the Russian chemist Mendeleeff. In fact, both of these men were following leads derived from fundamental considerations. Mendeleeff, in constructing his periodic sequence according to properties of the elements, noted a blank in Group IIIb immediately under aluminum and said that an element "eka-aluminum"

*Product Manager, Chemical Products, Aluminum Co. of America, Pittsburgh.

would be eventually found to fit the space. De Boisbaudran, studying the spectral lines of the elements, noted a definite periodicity, and an element missing between aluminum and indium which he searched for and found in a zinc ore from the Pyrenees. Since then, scientists, researchers, and development engineers have spent some effort, with small success, on finding profitable uses for the unique metal.

Like several of the elements, gallium is a silvery white metal, but unlike all others, it melts at 86° F. (30° C.) and remains a liquid until approximately 3600° F. (1980° C.). This extremely long liquid range prompted de Boisbaudran to suggest its oldest application – in place of mercury for high-temperature thermometers. Unlike mercury, it is nontoxic. In its newest use, gallium's low melting point was utilized to place liquid metal in the joint sleeves of glass laboratory apparatus.

When atomic energy power plants became a probability, gallium's long liquid range and low vapor pressure invited attention as a heat-exchange medium. But the metal's trait of "wetting" almost everything, including glass, stymied the proposal. Even though this property appears to be due to traces of oxide, in the gallium or on the object, truly oxygen-free conditions are very difficult to produce and maintain.

A summary of gallium's properties as a heat transfer medium is given in the 2nd Edition of the Atomic Energy Commission's "Liquid-Metals Handbook". In this same book may be found the following cross sections for thermal neutrons.

Isotope No.	69	70	71	72
Abundance (natural)	61.2%	–	38.8%	–
Cross section	1.4	–	3.4	–
Half life	–	20 min.		14.1 hr.

(All isotopes from 64 to 73 have been prepared.) The cross sections of the natural isotopes are rather high in comparison with sodium (0.45) or aluminum (0.21), but still are not too high for consideration. The greatest drawback of gallium is that at elevated temperatures it attacks solid metals and can be contained only by quartz, graphite, alumina and some other refractory oxides, and the metals tungsten and tantalum. Gallium's ability to wet, however, and to reflect a high percentage of incident light led to its limited use as a backing for optical mirrors.

As one of the few metallic elements having greater density as a liquid than when solid (bismuth and antimony being two others), gallium presents an interesting packaging problem. Alcoa prevents loss or contamination of shipments by packaging liquid gallium in rubber bulbs and plastic capsules to allow for the 3.1% expansion of volume upon freezing. This unusual characteristic has suggested that it can be used to obtain high pressure at low temperatures; it also improves gallium's efficiency as a sealant in vacuum equipment.

Experiments with gallium as an alloying material have shown that a small amount increases the hardness of ternary aluminum alloys. Tests recently completed at Alcoa Research Laboratories indicate that in severely corrosive environments, gallium improves the resistance to corrosion of commercially pure magnesium and of a Mg-Sn binary alloy. A rather comprehensive review of what is known about gallium alloys is contained in Argonne National Laboratory Report No. 4109.

Its most successful application, however, has been in gold alloys used in dental work. In a test of strength, such an alloy, mixed in a mortar and pestle and formed into a filling with a cross-sectional area of 0.03 sq.in., supported a 2000-lb. weight – equivalent to 66,000 psi.

But these and other uses have generated only a small demand for gallium. Cost is high because of the complicated processing methods required to produce the metal; it costs $3.00 to $3.50 per g., depending on the size of the order.

Gallium occurs only in minute quantities in bauxite, zinc ores, and in coal. Alcoa refines gallium from the Bayer process solution as a by-product in making alumina, the feed for the electrolytic cells producing aluminum metal. Other firms extract it from the residues of zinc distillation plants. British metallurgists have estimated that 2,000,000 lb. of gallium is left behind in the ash and soot of coal burned yearly in England. The gallium-rich residues are concentrated and refined chemically into a solution in caustic soda, and then electrolyzed between insoluble anodes. The gallium drips off the cathode. Later purification depends on the fact that gallium may be supercooled some 50° C. below its real freezing point. The supercooled metal is seeded with a small crystal of gallium and the crystal grows rapidly, the impurities tending to remain in the liquid. When most of the liquid has crystallized, the solid is removed, and the process repeated until the desired purity is reached. This process has certain similarities to the "zone refining" methods for producing germanium crystals for transistors. Germanium, by the way, is next-door neighbor to gallium in the periodic sequence.

Automatic Ratio Control for Endothermic Gas Generators

*By H. N. IPSEN**

A new instrument for automatic control of air and gas ratio fed to endothermic gas generators assures accurate control of composition of the output gas. (J 2, S 18)

COMPLETELY automatic carbon potential control of furnace atmospheres has not been possible because of inevitable fluctuations in composition of the carrier gas produced in conventional endothermic gas generators. With small variations in composition of the A.G.A. Type 302 gas, automatic equipment such as that described in "Automatic Carbon Control" in *Metal Progress*, July 1954, will provide adequate control of the furnace atmospheres. An excessive variation in composition is difficult to handle and correction may be either too slow or inaccurate.

The most important factor which influences the composition of the endothermic gas is the ratio between the amounts of air and gas fed into the generator. A slight change in this ratio will produce a disproportionally large change in the carrier gas composition, as indicated in Table I. The dew point, which is used to control carbon potential of the furnace atmosphere, is appreciably affected; an increase in the ratio of air to gas from 2.5 to 2.75 increases the dew point from 7 to 46° F.

Table I – Composition of A.G.A. Type 302 Gas Produced With Different Ratios of Air to Gas

Ratio of Air to Gas	Dew Point	H_2	CO	CO_2	CH_4
2.50	7° F.	39.5	19.9	0.1	0.6
2.65	26	38.6	18.5	0.4	0.4
2.75	46	38.4	17.4	0.6	0.3

The temperature at which the generator operates also has an effect on gas composition but at temperatures above 1800° F. the effect is negligible. Other variables include the time required for the gas to pass through the catalyst, the activity of the catalyst and the humidity of the air. Most generators have a range of capacity over which the gas produced will be of uniform composition. Deviations from this range will cause fluctuation of the dew point, which must be corrected by adjusting the air-to-gas ratio.

Although the air-to-gas ratio is the most important variable, it has until now required manual control which can never be as precise as instrument control. In order to evaluate the magnitude of dew point fluctuation of the carrier gas under typical operating conditions, a Dewtronik instrument was attached to a gas-fired generator which was set to produce a gas with a dew point of +25° F. with a variation of ±5° F. The variation of dew point under manual control is shown in Fig. 1.

At the start (bottom of chart), the operator found the dew point to be 40° F. He turned the ratio control knob to correct it and several min-

*President, Ipsen Industries, Inc., Rockford, Ill.

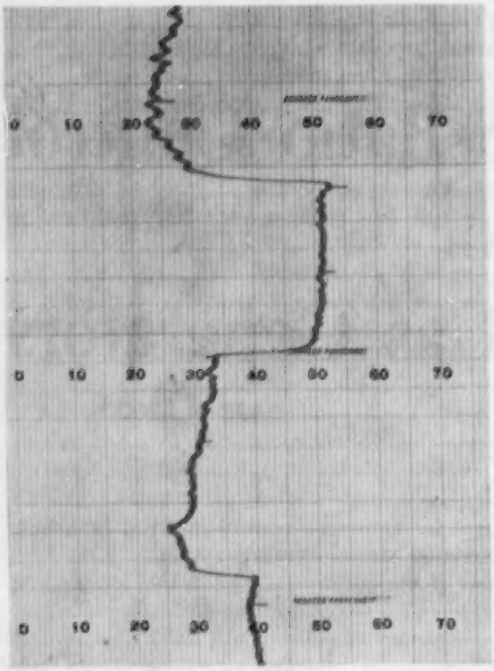


Fig. 1 – Dew Point Fluctuation of Endothermic Gas Under Manual Control

utes later another check showed that the dew point was now within the prescribed range and the atmosphere under control. After one hour, one or a combination of factors forced the dew point up and out of control range. To correct it, the operator again turned the knob – but inadvertently in the wrong direction! Assuming that the adjustment was correct he did not check the dew point again for another hour. In the meantime, this generator supplied carrier gas to three furnaces and they were all out of control.

This situation is typical; the "human element" makes it difficult to keep the carrier gas within control limits in spite of the fact that the air-to-gas ratio can be controlled easily by manual adjustment.

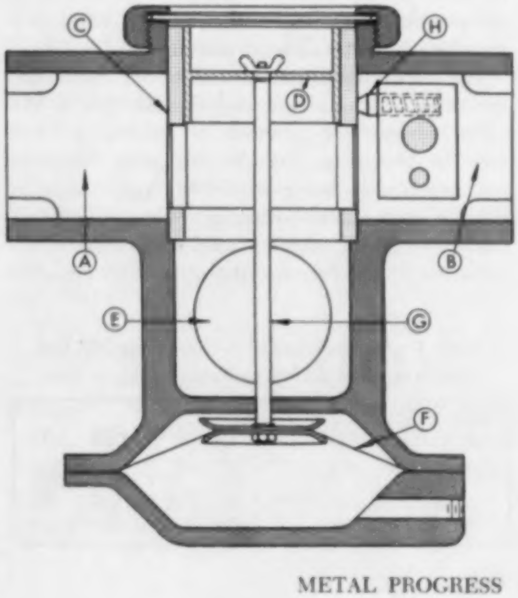
The Dewtronik system of composition control was evaluated carefully for about a year by comparison with control by hydrogen determinations. The dew point measurements proved to be a more reliable method. Dew points were actually taken every 2 to 3 sec. Equipment for detecting methane, carbon monoxide and carbon dioxide was not included due to lack of practical commercial units.

Automatic control required the design and perfection of a control interlock arrangement that would regulate the air-gas mixer according to the dew point instrument readings. One major problem was the accurate expansion of the gas to atmospheric pressure to insure that both air and gas would enter the mixing chamber at equal pressure.

The new mixer, shown in Fig. 2, utilizes a cylindrical valve with rectangular ports for air and gas. A piston, moving vertically within this valve, is actuated by a diaphragm back-loaded against the air supply. As generator output fluctuates, this piston controls the volume of air and gas being fed to the mixer. The air-gas ratio remains constant. To set the ratio, a control knob is turned. It changes only the size of the air port opening by rotating an adjustable sleeve.

The adjusting rod and knob were extended beyond the side of the casing, a clutch and sprocket attached, and a 1/50-hp. reversing motor connected to it by a chain. A clutch was included for manual adjustments. The drive motor was then connected to the control contacts of the Dewtronik and "floating control" attained with the motor constantly in motion at a speed of about 2 revolutions per hr. Floating control of this type is considered the most sensitive since no dead spots or neutral positions are involved. Control is constant and speed of response is rapid

Fig. 2 – Cross Section of Special Air-Gas Mixer Developed for the Automatic Endothermic Generator. A – Gas, B – Air, C – Cylinder with port, D – Piston, E – Mixer outlet, F – Diaphragm, G – Connecting rod, H – Rotating sleeve mechanism



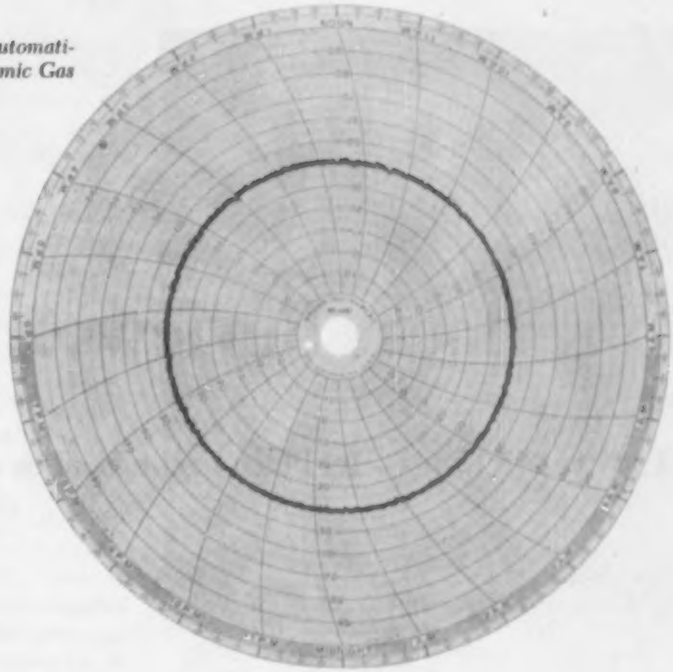
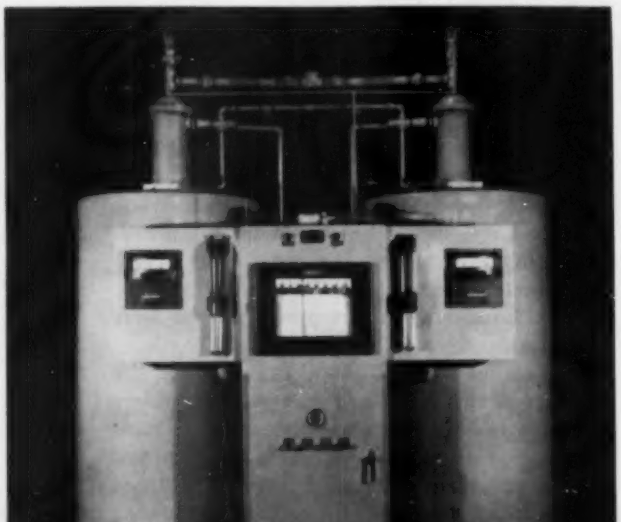


Fig. 4 – Dew Point of Automatically Controlled Endothermic Gas

enough to return the air-gas ratio to the required level before any damage is done. In operation, it was found that generator response to any changes in the air-gas ratio was on the order of 10 to 15 sec. at rates as rapid as 15 dew-point degrees per min. These rates were achieved under maximum flow and capacity conditions.

The first combination controller-generator was housed in a common shell and the unit placed on final test early in 1955. The generator was dried out and the unit placed on manual control for several weeks. At the end of this time, the atmosphere sampling line from the generator outlet was opened and carrier gas filtered and passed to the voltage-type sending head. Flow was about 25 cu.ft. per hr. at 9 oz. pressure. In the Dewtronik system, the actual dew-point temperature is detected by a copper-constantan thermocouple in the sensing head, connected to a potentiometer. This instrument has a full scale travel of 5 sec. which is sufficient speed for the response of the Dewtector.

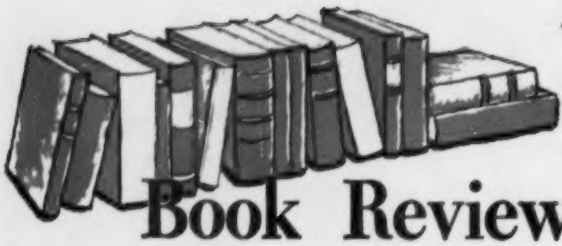
Fig. 3 – Ipsen Automatic Endothermic Generator



After a few days of continuous operation, the motorized control knob was energized. For a period of three months, satisfactory continuous automatic control could not be obtained because of a number of minor modifications and adjustments necessary in the mixer and control system. Finally, the unit shown in Fig. 3 was ready and for the first time fully automatic control of an endothermic generator was achieved.

The chart in Fig. 4 shows the degree of control possible in a 24-hr. period. The oscillations indicate the floating control action of the air-gas mixer motor. They can be varied by changing the drive ratio between the motor and the control knob sprocket. The most satisfactory oscillation has been found to be about $\pm 1^\circ$ F.

The fully automatic control of an endothermic gas generator eliminates the last variable, namely, carrier gas composition, which has prevented full automation of controlled-atmosphere processing equipment. Manual generator adjustments can now be eliminated, technician attention minimized and periodic burnouts and downtime for maintenance considerably reduced. Last but not least, control of the atmosphere in a furnace can now be more rapid and accurate.



Book Review...

Electric Melting — Its Place in the Economic Scheme

*By E. C. WRIGHT**

ELECTRIC MELTING AND SMELTING PRACTICE, by A. G. E. Robiette, Charles Griffin and Co., Ltd., London. 347 p., 1955, 50 s.

The strange economic paradox of a steady or declining cost of electric power while the cost of all other sources of thermal energy has increased sharply has precipitated much new interest among engineers in all types of electric furnaces. Highly industrialized nations have had to increase electric power output to keep up with the growth of industry, and many backward nations are expanding electric output so as to develop new industries.

This book is therefore most timely, particularly as a reference book for the many metal producers who are currently studying the comparative merits of electric furnaces and older types of fuel-fired equipment. It is the most complete and detailed summary of electric furnace design, operation, heat balances, and costs that have ever been assembled in one volume. It reflects the author's long experience in many countries, and is written in a clear and lucid style.

The first three chapters are concerned with the application of arc furnaces for the melting of steel, cast iron and nonferrous metals and alloys; two chapters cover the various types of induction furnaces; others are on resistor melting furnaces, pig iron smelting, ferro-alloys, and the electric smelting of nonferrous metals. Each chapter contains a complete description of furnace construction, plant operating details, heat balances, and in most instances operating costs. An extended bibliography for each chapter lists all important pertinent papers.

The reviewer found the first three chapters on melting of most interest. It has long been admitted that the quality of most metals and alloys is better and more uniform when they are melted electrically than when processed in fuel-fired furnaces. In the past electric energy has been more costly than energy from mineral fuels, but this economic gap is narrowing every year. The high thermal efficiency of large electric furnaces (about 80% as compared to about 20% for fuel-fired furnaces) also has a strong bearing on the comparative merits. Larger furnaces with better control equipment have been developed; faster melting and lower labor charges are also important. Technical advantages of large electric furnaces include fast heat input, higher temperatures more easily regulated, better control of furnace atmospheres and slags with more desirable refining conditions for finishing the melts.

The author devotes about one third of the book to electric steel and iron melting. Every known type of furnace is described, with details on electric equipment, controls, refractories, electrodes, and other auxiliaries. Heat balances, melting rates, charging and slagging methods are included with actual heat logs as examples. New developments such as removable tops, top charging and oxygen blowing are fully described. Most of the data in the Battelle report on comparative capital costs, operating costs, and melting rates of electric arc versus openhearth steel furnaces

*Head, Department of Metallurgical Engineering, University of Alabama, University, Ala.

are reviewed and analyzed from a British point of view. Much of this material relates to small furnaces (10 to 25 tons) which are typical of foreign plants, and too little data are given for the much larger furnaces (100 to 200 tons) now being built in the United States. The higher power input for faster melting, made available through larger transformers, is emphasized; power on newer furnaces per ton of holding capacity has more than doubled in the past 20 years. Thermal efficiencies for various sizes of furnaces are also compared.

In the chapter on cast iron melting, the author concedes that for ordinary gray iron the cupola furnace is considerably cheaper both in fuel cost and capital investment. He bases his opinion on cupola cost of $25 per net ton of coke at 178 lb. of coke per ton of iron melted as against 1¢ per kw-hr. at 446 kw-hr. per ton of iron for the electric furnace. Since several large electric furnaces are melting steel with all-cold-scrap charge at 500 kw-hr. per ton, the power figure given for cast iron melting seems high. Many tons of cast iron have been melted in the U.S. at a power consumption of 350 to 400 kw-hr. per net ton.

The chief advantages of the electric furnace are for melting low-carbon malleable cast iron (2.5 to 3.0% C), alloy cast iron such as Ni-Resist, austenitic irons, and for mass production of such special products as piston rings. Here the more accurate and uniform control of temperature and composition makes electric melting superior. Electric furnaces (either direct or indirect-arc) are also widely used for melting cast iron borings or steel turnings. Much space is given to the indirect-arc rocking furnace and its advantages for melting small heats of special irons (less than 1000 lb.) in jobbing foundries and for melting borings with little oxidation or metal loss (3 to 5%).

The author also emphasizes the value of duplexing cupola iron in electric furnaces and advocates this practice in mass-production foundries, especially for malleable iron. The low sulphur content of electric-furnace irons is stressed. No mention is made of nodular iron melting in the electric furnace but the low sulphur factor should be of great advantage for this application.

Two chapters are devoted to induction furnaces, one for normal frequency (25 to 60 cycles) and the other for high frequency. Complete details and references are given on construction, operation and applications with particular emphasis on electrical characteristics and refractories. Very little is said about the new use of high-frequency furnaces for vacuum melting.

Courtesy Westinghouse

Smelting of pig iron and other nonferrous metals is illustrated by descriptions of most of the successful installations for smelting ores direct in electric arc furnaces. The author has apparently had much experience in this field. He states that up to 2,000,000 long tons of pig iron is now being produced in areas where electric power is cheap and high-grade coal and coke not available. Power consumption approximates 2250 kw-hr. per net ton of pig iron with ores containing 50% iron. Most of these smelters are in Scandinavian countries, Italy and Switzerland; also a 15,000-kva. furnace is to be built in Brazil. Capacity of such furnaces is less than 50 tons per day; power supply ranges from 6000 to 12,000 kva. Since coke costs have increased greatly during recent years, there is much new interest in these electric furnaces for producing pig iron, especially in Canada and the Pacific Northwest where good coal is scarce and good iron ore and electric power are available. The author compares the relative thermal efficiencies of the standard coke blast furnace with the electric furnace and admits that the blast furnace is much superior. Electric power at a cost of 5 mils per kw-hr. would be required to make the arc furnace competitive.

Correspondence...

Should High-Strength Parts Be Prestressed?

COPAIGUE, N.Y.

As designers and manufacturers of store suspension equipment, we read with great interest the article by Jerome W. Kaufman entitled "Prestressing an Ultra High-Strength Steel to Perform Even Higher Duty" in the May 1956 issue.

We do considerable work in the field of high-strength materials used for hooks in bomb racks and explosive ejectors and have tried prestressing, shot peening and high-temperature baking to improve static and fatigue strengths of various components. We have conducted a great deal of development and research in order to avoid the use of prestressing as described in Mr. Kaufman's article. Although prestressing results in improved fatigue characteristics the resultant distortion of the hook pivot points and bearing surfaces plus the cracking of the chromium plating more than wipe out this advantage. The bearing face of the hook is essentially a friction surface whose relative smoothness must be maintained for reliable operation of the mechanism. We have avoided the use of prestressed hooks in many of our successful designs by paying close attention to stress concentration points and maintaining good quality control of heat treating, plating and stress-relieving procedures.

There was some discussion in the article as to the use of "Super Hy-Tuf" steel in the 280,000 to 300,000-psi. range as a hook material. Our work indicates that this material has considerable merit; however, the problems of notch sensitivity, room-temperature stress-rupture properties and lack of uniform cleanliness have thus far been a deterrent to its general use.

Studies made at the University of Pittsburgh have indicated that aircraft quality S.A.E. 4140, when properly processed, is still the most reliable material to use for bomb rack hooks.

Mr. Kaufman's excellent article points out one of the knotty problems that designers of this type of equipment encounter regularly. There are many other components which require high tensile strength, good corrosion resistance and high stress-rupture and fatigue characteristics. There is much that the metallurgists have yet to do in this aircraft armament program.

R. E. KEMELHOR
Chief Engineer
McLean Development Laboratories

Only a Delay in Delayed Cracking

WASHINGTON, D.C.

In my article "Delayed Cracking of Rolled Ti-150 A" published in the May issue of *Metal Progress*, I gave the impression that cross rolling prevented delayed cracking. This was true at the time the article was written, about six months after the work was done. I had occasion to check the specimens recently (six months later) and found the cross-rolled strips split right down the middle. Evidently, cross rolling only increased the time for crack initiation. To prevent delayed cracking, it is necessary to eliminate the high residual stresses in the strip ends either by cropping or by a suitable heat treatment.

HAROLD BERNSTEIN
U. S. Naval Gun Factory

The Greeks Haven't Named It

BOSTON

W. L. Havekotte's stress-rupture data for A.M.S. 5616 B shown in the May issue of *Metal Progress* are of considerable technological importance but I am very sure that the nominal composition which he sets forth would not have the properties indicated.

The analysis of A.M.S. 5616 B is based on U.S. Patent No. 2,227,891 issued to me and requires the presence of nickel to extend the gamma loop and thus permit the formation of austenite on heating and martensite upon quenching. Hence, in this composition 1½ to 2½% nickel is essential.

We also have a mild objection to labeling this alloy "Greek Ascoloy". It is not Ascoloy and the only things Greek about it are the alpha and gamma phases which, as in all martensitic alloys, are present at room temperature and at high temperature, respectively.

ROBERT S. ROSE
District Manager
Latrobe Steel Co.

PITTSBURGH

The nickel content was inadvertently omitted from the nominal composition of the alloy whose properties were described. It did contain 2% nickel.

Concerning Mr. Rose's mild objection to labeling this alloy "Greek Ascoloy", we use this terminology because of its general acceptance. Any suggestions for another name for the alloy would be appreciated.

W. L. HAVEKOTTE
Manager, Cermet Research
Firth Sterling, Inc.

Personal Mention

Col. A. W. Sikes

Colonel ALFRED W. SIKES ⊕ has retired from the Chemical Corps, U.S. Army Reserve, shortly after receiving the Armed Forces Reserve Medal for more than 30 years' service in the U.S. Army and active reserve.

After graduation from high school in 1917, young Sikes entered the Army and served for one year. In 1920 he joined the Western Electric Co. in Chicago, leaving there after one year, but returning in 1922 to become a chemical and metallurgical engineer in the development branch of the Western Electric Hawthorne plant. During these years, he attended Lewis Institute evening school (where he later served as head of the school's evening metallurgy classes). Colonel Sikes graduated from the University of Illinois in 1926 and two years later received his Master's degree from Carnegie Institute of Technology, where he was a research fellow in metallurgy.

In 1933 he became senior chemical and metallurgical engineer for the Public Works Administration in Washington, D. C., and Chicago, advising on engineering materials and general engineering problems.

A reserve commissioned officer since 1924, Colonel Sikes was recalled to active duty in 1940 and spent the war years in the Chemical Corps in the Mediterranean theater. He was discharged in 1946 with the rank of colonel in the Chemical Corps reserve. Since his discharge he has been a specification engineer with the Chicago Park District.

Colonel Sikes is a member of several technical organizations. He is a past chairman (1933) of the Chicago Chapter of ⊕, and the first president of the Chicago Chapter of the Construction Specifications Institute.

John S. Marsh

John S. Marsh ⊕ has been named manager of research, Bethlehem Steel Co., Bethlehem, Pa.

After graduation from Pennsylvania State University in 1927 and a year of graduate study, he began his professional career in the engineering department of the Aluminum Co. of America. In 1930 he left to join the Engineering Foundation in New York as a metallurgist. During his 12 years as metallurgist and editor for the Foundation, Mr. Marsh worked on the "Alloys of Iron" monographs, and is the author of several of the volumes. In addition to this position, he served as adjunct professor of physical chemistry and metallurgy at Brooklyn Polytechnic Institute (1939 to 1942) and as a lecturer at Stevens Institute of Technology (1941 to 1942).

In 1942 Mr. Marsh came to Bethlehem Steel as a research metallurgist, holding this position until 1953 when he was named assistant manager of research.

In recognition of his contributions to his field, Mr. Marsh has been honored several times. The Hunt Medal of the American Institute of Mining, Metallurgical and Petroleum Engineers was awarded him in 1950 and the American Iron and Steel Institute Medal a year later. He also received the Stoughton Award "for outstanding contributions to metallurgy" from the Lehigh Valley Chapter of the American Society for Metals. Last year Mr. Marsh was the Howe Memorial lecturer for A.I.M.E.

Mr. Marsh belongs to numerous technical societies and government committees. He served as chairman of the New York Chapter ⊕ in 1938 and was chairman of the Iron and Steel Division of the A.I.M.E. in 1954.

Bernard W. Wittig ⊕ has joined the B. & W. Precision Heat Treating Co., Kitchener, Ont., as works manager. Mr. Wittig formerly spent 11 years as a metallurgical engineer with the Morrow Screw & Nut Co.

Earl C. Beatty ⊕ has been named chief metallurgist at the Halethorpe, Md., extrusion works of the Kaiser Aluminum and Chemical Corp. Prior to joining Kaiser Aluminum a year ago, Mr. Beatty had been associated with the U.S. Bureau of Mines for 10 years.

John E. Chard ⊕ has joined the staff of the International Nickel Co.'s Bayonne, N. J., research laboratory as a mechanical engineer. A native of England, Mr. Chard came to North America in 1953 to take the position of chief metallurgist at the Canadian Armament Research and Development Establishment, Quebec, and held this position until his recent appointment.

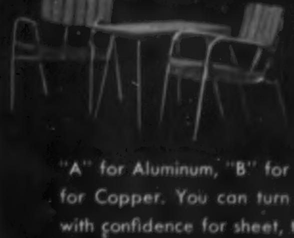
John A. Whitehead ⊕ was recently appointed to the newly created position of product service engineer for the Park Alloy and Carbon Div., Crucible Steel Co. of America, Pittsburgh. An employee of Crucible since 1953, Mr. Whitehead formerly was a metallurgist at the Park Works.

Why this ALUMINUM furniture has one touch of BRASS

The Troy Sunshade Company knows that fine products must start with fine materials. That is why Troy uses Revere Aluminum Tube for its distinctive lines of lawn and patio furniture. The aluminum is even gold-anodized to give it a rich golden color and extra surface protection.

But a further problem in metals arose. A Revere Technical Advisor was called in to study the metal requirements of the umbrella's patented tilting mechanism. It had to be strong, highly corrosion-resistant, easily machinable and provide a color match with the golden-hued aluminum. Revere Naval Brass was recommended, was adopted, and proved ideal.

Here is striking evidence of the wisdom of bringing your metal problems to Revere. For Revere can be impartial because it knows its A-B-C's—



"A" for Aluminum, "B" for Brass, "C" for Copper. You can turn to Revere with confidence for sheet, tube, pipe, extruded shapes, bus conductors, forgings and foil. Why not call the nearest Revere Office now? In all principal cities.

REVERE COPPER AND BRASS INCORPORATED. FOUNDED BY PAUL REVERE IN 1801. EXECUTIVE OFFICES: 230 PARK AVENUE, NEW YORK 17, N. Y.

Personals . . .

P. B. Kline has been named manager, stainless steel, at the Edgcomb Steel Co., Philadelphia. Mr. Kline came to Edgcomb six years ago from the rustless division of Armco Steel Corp., and until his recent appointment served as product manager, stainless steel sales.

Robert K. Wawrousek was promoted to chief metallurgist of the Parish Pressed Steel Div. of the Dana Corp., Reading, Pa. Mr. Wawrousek, who has been with Parish for seven years, formerly served as assistant metallurgist.

Jack D. Ramsdell is now a physical metallurgist in the rare and precious metals experimental station, U.S. Bureau of Mines, Reno, Nev. Prior to this position, Mr. Ramsdell was a metallurgist at the U.S. Naval Ordnance Test Station, China Lake, Calif.

Mervin S. Allshouse Jr., formerly project engineer with the Amplex Div., Chrysler Corp., Detroit, is now an engineer with the atomic power division of Westinghouse Electric Corp., Pittsburgh.

Kenneth M. Acton, formerly assistant manager of the San Francisco sales office of Crucible Steel Co. of America, Pittsburgh, has been named manager of the San Francisco sales office. Mr. Acton has been employed by Crucible since 1941.

William Thomas Kluge has been assigned to Nagoya, Japan, as a production development laboratory specialist under the U.S. Air Force as part of the technical support program of North American Aviation, Inc., to Shin Mitsubishi Aircraft Plant. The Japanese company is building F-86F airplanes for the Japanese Air Self-Defense Force.

Robert W. Sandelin recently graduated from the Birmingham School of Law and was admitted to the Alabama Bar. Dr. Sandelin is chief metallurgist and in charge of steel melting at the Connors Steel Div. of H. K. Porter Co., Inc., in Birmingham. In addition to this post, he also is a technical director for Alloy Metal Wire, a division of H. K. Porter Co., Inc., in Prospect Park, Pa., acting there as an advisor on metallurgical research and development activities.

Personals . . .

Leonard R. Kohan Ⓜ has left his position as senior electroplating engineer with Bell & Howell Co., Chicago, to accept a position in the electrochemical section of the metals department, Armour Research Foundation, Chicago.

R. O. Peterson Ⓜ was recently elected vice-president, brush division – engineering, Osborn Mfg. Co., Cleveland. Mr. Peterson has been with Osborn since 1936, joining the company as technical department manager.

Robert T. Howard Ⓜ has joined the staff of the James W. Weldon Laboratory, Kansas City, Mo., as director of the recently expanded metallurgical laboratory facilities. Dr. Howard was formerly staff engineer at Bendix Aviation Corp., Kansas City, Mo.

Ernest Peters Ⓜ has been promoted from senior laboratory technician to engineer at Atomics International, Los Angeles.

Joseph Kozol Ⓜ, a recent graduate of Case Institute of Technology, has entered the U. S. Army as a second lieutenant in the Signal Corps for six months training.

William F. Anderson Ⓜ has been appointed office manager for the Solar Steel Corp.'s Nashville, Tenn., plant. Mr. Anderson previously had been manager of orders and purchasing for the Osco Steel Co., Cleveland.

Charles E. Brown Ⓜ has been appointed executive vice-president of Chemstone Corp., Cleveland. For the past 20 years Mr. Brown has held various positions in the Minerals & Chemicals Corp. of America, the parent company of Chemstone, and most recently served as administrative assistant to the president of Minerals & Chemicals.

W. B. Brooks Ⓜ was recently promoted to senior metallurgist in the electrochemical engineering department of the Freeport, Tex., division of Dow Chemical Co. Joining the Texas division in 1948, Mr. Brooks was assigned to electrochemical engineering as a research and development engineer, holding that position until his recent appointment.

FREE

CHASE BRASS & COPPER CO. Dept. MP-856
Waterbury 20, Conn.

Gentlemen:

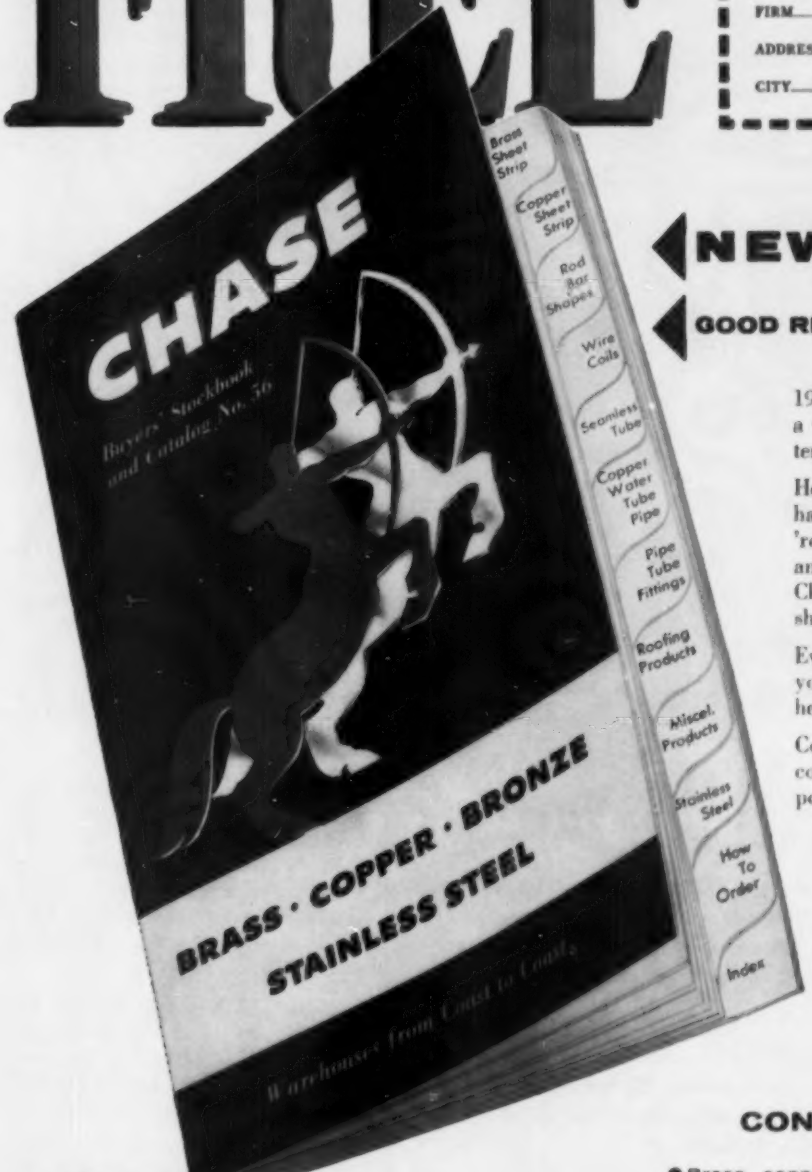
Please send me your free 192-page Buyers Stock Book and Catalog No. 56.

NAME____________________

FIRM____________________

ADDRESS____________________

CITY__________ STATE__________



NEW EDITION!

GOOD READING FOR METAL MEN!

192 pages of illustrations and listings of a variety of products...sizes...weights...tempers...shapes!

Here's the latest enlarged edition of a handy desk-sized book you'll use all year 'round! It lists the brass, copper, bronze and stainless steel mill forms carried in Chase warehouse stocks—ready for quick shipment to you!

Everything about it is designed to save you time, from its thumb-indexing to a headache-saving *how-to-order* section.

Comes to you *free* from Chase. Get your copy by filling out and mailing the coupon above. Do it today!

CONTENTS INCLUDE:

- Brass, copper, bronze, stainless steel rod, bar, sheet, strip, wire, tube, pipe, angles, channels.
- MISCELLANEOUS ITEMS, TOO—bolts, nuts, washers, rivets, burs, nails, tacks, screws, cotter pins, bearing bronze, copper roofing products, wire cloth, insect wire screening, etc.

Chase®
BRASS & COPPER CO.
WATERBURY 20, CONNECTICUT • SUBSIDIARY OF KENNECOTT COPPER CORPORATION

The Nation's Headquarters for Brass, Copper and Stainless Steel
Atlanta Baltimore Boston Charlotte Chicago Cincinnati Cleveland Dallas Denver Detroit Grand Rapids Houston Indianapolis Kansas City, Mo. Los Angeles Milwaukee Minneapolis Newark New Orleans New York Philadelphia Pittsburgh Providence Rochester St. Louis San Francisco Seattle Waterbury

Personals . . .

A. H. Lewis Ⓜ has been appointed manager of toolsteel sales for Crucible Steel Co. of America, Pittsburgh. Mr. Lewis was a member of the sales staff of Crucible for a number of years, but in 1954 left the company to join Vacuum Metals Corp., Syracuse, N. Y., as sales manager. He held this position until his new appointment.

W. B. F. Mackay Ⓜ has joined the metallurgical service department of Atlas Steels Ltd., Welland, Ont. Before coming to Atlas, Dr. Mackay was assistant professor of metallurgical engineering at the University of Minnesota.

James J. Curran Ⓜ, after 20 years with the Walworth Co., New York, has retired to become an assistant professor in the department of metallurgical engineering at the School of Mines of the University of Pittsburgh. Mr. Curran also plans to devote a portion of his time to general metallurgical and foundry consultation work.

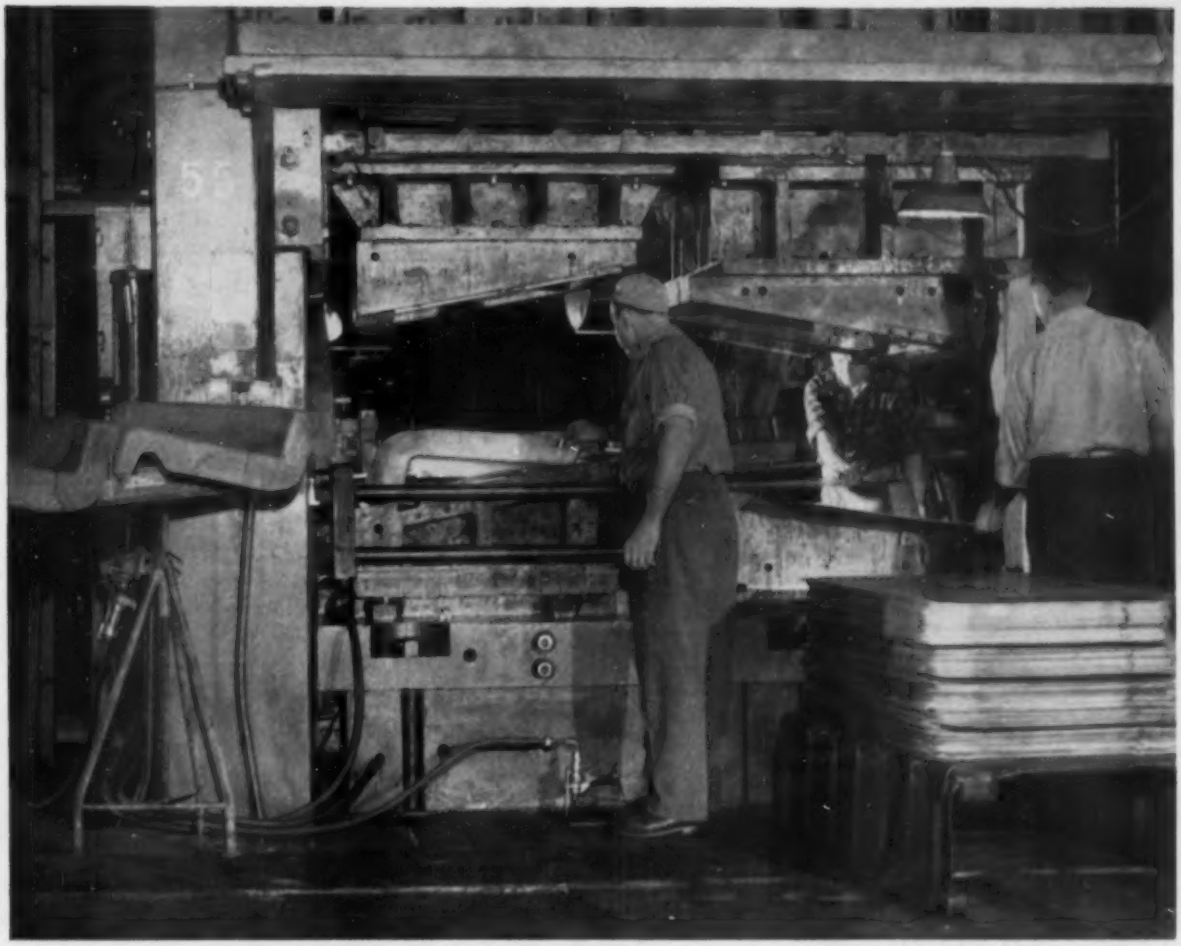
William E. Shenk Ⓜ has been appointed director of electrical engineering of the McKay Machine Co., Youngstown, Ohio. Mr. Shenk first came to McKay in 1950 as an electrical engineer.

Rupert E. Key Ⓜ, formerly a materials and process engineer with Lockheed Aircraft Corp., Burbank, Calif., is now a welding engineer in the fabrication laboratory, development shop section of the Army Ballistics Missile Agency, Redstone Arsenal, Huntsville, Ala.

Richard H. Haupt Ⓜ resigned as research metallurgist with the Glenn L. Martin Co., Baltimore, Md., to become a project engineer at Hunter Engineering Co., Riverside, Calif.

Frederick H. Meng Ⓜ is now assistant superintendent, no. 1, 2, 3 seamless hot mills, National Tube Div., U. S. Steel Corp., Lorain, Ohio. An employee of the Lorain division since 1933, Mr. Meng last held the post of assistant chief metallurgist.

Martin L. Anderson, Jr. Ⓜ, recently released from the U. S. Air Force, is now an application engineer with Ingersoll-Rand Co., Birmingham, Ala.



Personals . . .

Russell C. Buehl, formerly chief of the Bureau of Mines' pyrometallurgy laboratories in Pittsburgh, has joined the staff of Rem-Cru Titanium, Inc., Midland, Pa. Dr. Buehl will study and develop new melting techniques for titanium alloys.

William H. Kinney is now assistant to the vice-president, operations, for Kaiser Steel Corp., Oakland, Calif. Mr. Kinney was previously resident metallurgist for the company, engaged in customer contact work in northern California and the company's sales and metallurgical departments and operating divisions.

Charles R. Funk has been named manager of metallurgy and engineering of Alco Products, Inc., Latrobe, Pa. Mr. Funk, who joined Alco in 1942, last held the position of chief metallurgist.

John R. Bedell is now senior engineer in the fuel element department, nuclear engineering division of the Glenn L. Martin Co., Baltimore, Md. Mr. Bedell was previously associated with the Sylvania Electric Products, Inc.

James I. Barbier was recently assigned as a magnesium salesman for the Dow Chemical Co. at the Camden, N. J., sales office.

Robert P. Jensen has been appointed district manager of the newly created Boston district office of Kaiser Aluminum & Chemical Sales, Inc.

Donald B. Evans, formerly a student at Massachusetts Institute of Technology, is now a second lieutenant in the 18th Engineer Battalion (Combat), U. S. Army, stationed in Kassel, Germany.

Robert F. Meyers is now handling sales and engineering on color anodizing for Planetary Chemical Co., St. Louis, Mo. Mr. Meyers is also concerned with magnesium treatments and other special metal finishing applications.

Robert J. Rowe, a recent recipient of a Ph.D. degree from Michigan State College, is now associated with the metallurgical laboratory of the Dow Chemical Co., Midland, Mich.

"The right quench oil for our work is

SHELL VOLUTA OIL 23"

says Garland Wilcox, Chief Metallurgist
Wallace Barnes Co., Bristol, Conn.

. . . the story of a profitable change

WALLACE BARNES COMPANY and steel springs have "gone together" for nearly a century. Most of today's output is in SAE 1075 or 1095 steel.

Because the quenching operation is so important to the life of springs, the Wallace Barnes laboratory decided to test its regular quenching oil against some of the newer products, including Shell Voluta Oil 23. This is what they found:

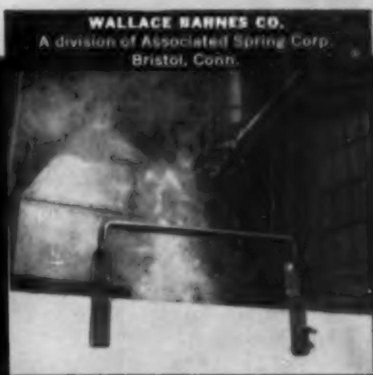
Shell Voluta Oil 23 showed a superior quench rate, with correct hardening and relative freedom from distortion. It drained more rapidly from the quenched parts, reducing dragout loss. It washed off more completely in the alkaline cleaner; it reduced flaming, and cut down on the oil baked to parts.

Wallace Barnes reports that this oil has almost eliminated trouble with "slack-quenched parts," and that heavier stock now goes through without special handling. So . . . Shell Voluta Oil 23 has replaced the former quench oil in all tanks of the spring hardening departments, serving salt pot lines and shaker hearth furnaces.

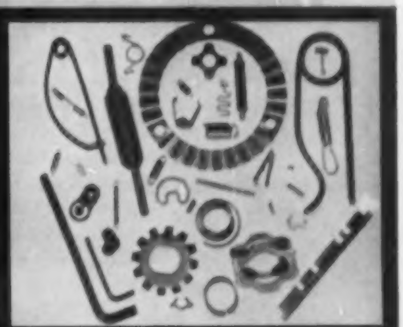
We'll be glad to provide full information on Shell Voluta Oil 23.

Photos courtesy "STEEL"

Shaker hearth furnaces automatically dump parts into Shell Voluta Oil 23, then remove and drain them.



Flat springs at austenitizing temperature get a fast quench in Shell Voluta Oil 23.



Over 35,000 prints of production items like these are kept on file at Wallace Barnes Co.

SHELL OIL COMPANY

50 WEST 50TH STREET, NEW YORK 20, NEW YORK
100 BUSH STREET, SAN FRANCISCO 6, CALIFORNIA

SHELL

Personals . . .

Joao Gustavo Haenel ⊕ has been elected a director of Companhia Siderurgica Paulista, Sao Paulo, Brazil.

Ernest F. Nippes ⊕ is conducting a research program on the hot ductility of alloy steels at Rensselaer Polytechnic Institute. This research program was contracted by the metallurgical engineering department of the M. W. Kellogg Co., Jersey City, N. J. as part of an extensive research and development program to study the high-temperature behavior of different heat resistant steels. Dr. Nippes is director of welding research at Rensselaer.

Robert Wheeler ⊕ has established his own business as a consultant in eastern Canada with headquarters in Ste. Foye, Que. Before coming to Canada two years ago, Mr. Wheeler was a consultant in the New York area for ten years.

J. E. Rehder ⊕, director of technology of Canada Iron Foundries, Ltd., Toronto, has been appointed vice-president of the company. Mr. Rehder is also the recipient of the 1955 Simpson Gold Medal from the American Foundrymen's Society.

Michael Lauriente ⊕, recent recipient of a doctor of engineering degree from John Hopkins University, is now with the air arm division of Westinghouse Electric Corp., Baltimore, Md.

John B. Girdler ⊕, formerly corporation sales manager of the Vanadium Corp. of America, New York, has been elected vice-president. Mr. Girdler will also fill the newly created position of general manager of sales. **Roy F. Hancock** ⊕, assistant vice-president, has been named to head the Corporation's new sales promotion division. **Howard H. Wilder** ⊕, formerly iron foundry division manager, has been appointed assistant manager of engineering sales.

Clee O. Worden ⊕ has been appointed sales representative for the Philadelphia district of the Northeastern Steel Corp., Bridgeport, Conn. Mr. Worden was alloy sales manager with the Horace T. Potts Co., Philadelphia, prior to his appointment.

Personals . . .

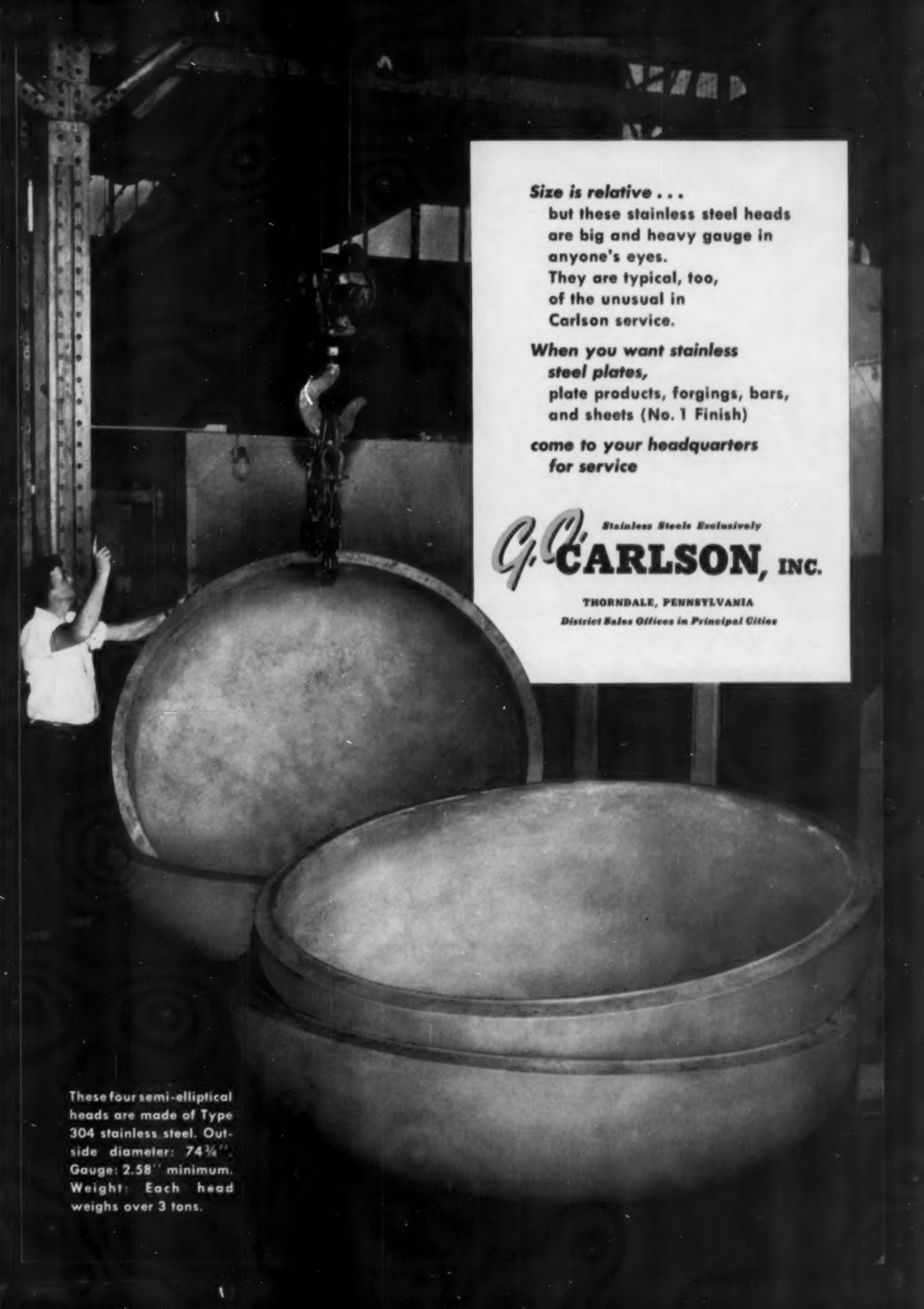
John W. Harsch, **William C. Dunn** and **Ernest G. de Coriolis** have been awarded the Trinks Industrial Heating Award for their contributions to the science of industrial heating. Mr. Harsch is director of engineering of Leeds & Northrup Co., Philadelphia. Mr. Dunn, founder of the Ohio Crankshaft Co., Cleveland, is chairman of the board of that company. Mr. de Coriolis has been director of research and development of the Surface Combustion Corp., Toledo, Ohio, for 30 years.

Edwin A. Gee, formerly manager of the technical section of the manufacturing division, E. I. du Pont de Nemours and Co., Wilmington, Del., has been appointed sales manager of pigment colors, pigment department, at Du Pont. **C. Ivey Smith, Jr.** has replaced Dr. Gee as manager of the technical section. Associated with Du Pont since 1946, Mr. Smith was formerly technical superintendent at the company's Newport, Del., titanium plant.

W. O. Binder is now assistant manager of the product and process development department of the Electro Metallurgical Co., a division of Union Carbide and Carbon Corp., Niagara Falls, N.Y. Mr. Binder has been associated with Electromet since 1936, first in the Metals Research Laboratories and more recently in the product and process department. **E. R. Saunders** has been named assistant to the manager and will be in charge of the product development laboratory. Mr. Saunders has been connected with the department since 1941.

W. A. Mudge has been appointed special representative on educational programs of the International Nickel Co. of Canada, Ltd. and its subsidiary, the International Nickel Co., New York. Dr. Mudge, who joined Inco's Bayonne, N. J., research laboratory in 1920, was named director of the technical service section and research division in 1947 and held this position until his recent appointment.

George Martin has accepted a job with the Chromizing Co., Los Angeles, as director of technical control.


Size is relative . . .
but these stainless steel heads
are big and heavy gauge in
anyone's eyes.
They are typical, too,
of the unusual in
Carlson service.
When you want stainless
steel plates,
plate products, forgings, bars,
and sheets (No. 1 Finish)
come to your headquarters
for service
Stainless Steels Exclusively
G. O. CARLSON, INC.
THORNDALE, PENNSYLVANIA
District Sales Offices in Principal Cities
These four semi-elliptical heads are made of Type 304 stainless steel. Outside diameter: 74¾". Gauge: 2.58" minimum. Weight: Each head weighs over 3 tons.

Personals . . .

Charles A. Mueller ⊕ has been named plant metallurgist of the Industrial Steel Treating Co., Oakland, Calif. Mr. Mueller was formerly chief engineer at Western Rock Bit Mfg. Co., Salt Lake City, Utah.

John T. Hodges ⊕ is now assistant to the director, technical services division, Jones & Laughlin Steel Corp., Pittsburgh. Coming to Jones & Laughlin in 1949 as a metallurgical investigator at the Cleveland Works, Mr. Hodges last held the position of contact metallurgist in the Pittsburgh plant.

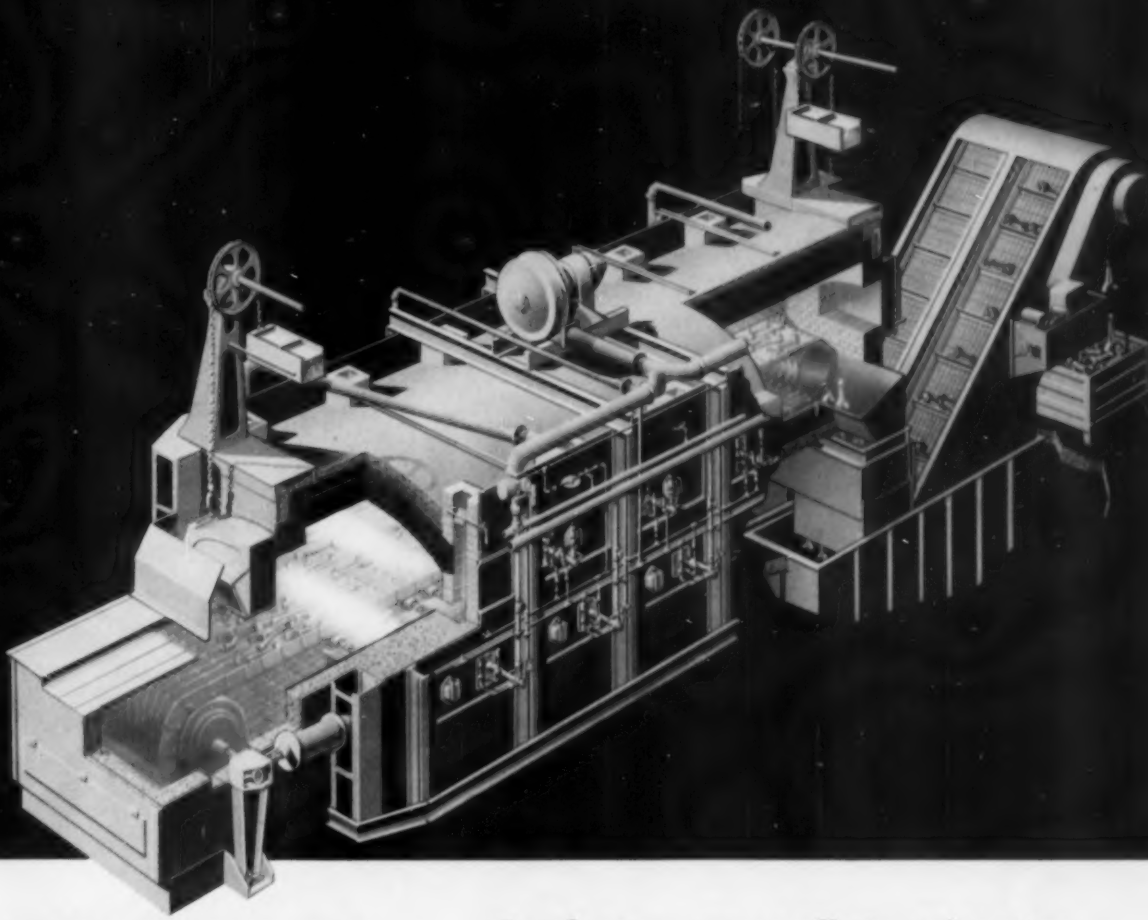
Leonard W. Kates ⊕ has been named manager of commercial development for the atomic energy division of Sylvania Electric Products, Inc., Bayside, N. Y. Since joining Sylvania in 1948 as an engineer in the advance development section of the metallurgical laboratory, Mr. Kates has served as head of the advance development section and more recently as engineering manager of the atomic energy division.

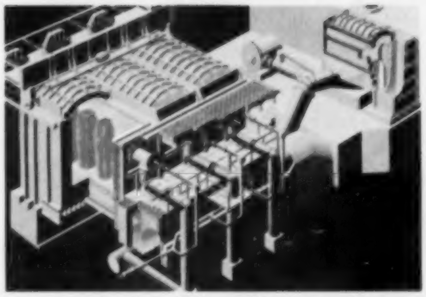
Mathew J. Donachie ⊕ resigned as president of the Beryllium Corp., Reading, Pa., recently so that he could devote his entire efforts to his work as director of research and development for the company. Mr. Donachie had been president of Beryllium since 1952.

George E. Rowan ⊕ has joined the metallurgical service department of Atlas Steels Ltd., Welland, Ont. Mr. Rowan, an employee of Atlas since 1952, was formerly superintendent of the stainless strip and tube department.

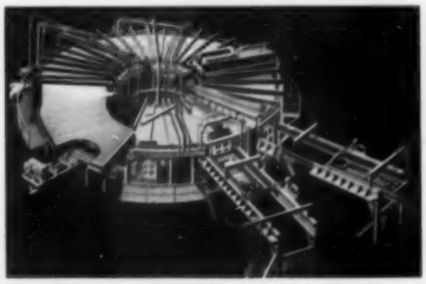
Arthur J. Williamson ⊕ has been promoted to executive vice-president of the Tube Reducing Corp., Wallington, N. J. Mr. Williamson joined the company in 1951 as vice-president and prior to that was plant manager of the Carnegie, Pa., plant of the Summerill Tubing Co.

William F. Burchfield ⊕ has been appointed supervisor of technical service in the International Nickel Co.'s development and research division. Mr. Burchfield has been with the Inco development and research division for 27 years, serving as assistant director of technical service since 1947.





Fast heating, high production soaking pits are a specialty of Salem-Brosius.



Salem-Brosius has earned world-wide recognition for rotary hearth furnaces.

For faster, more efficient heating or heat-treating furnaces, it pays to call on Salem-Brosius

Throughout the entire metals industry, Salem-Brosius designed furnaces are doing an efficient, low-cost job of heating and heat treating. The hardening furnace shown above in cut-away scale drawing is typical of high production heat treating furnaces by Salem-Brosius.

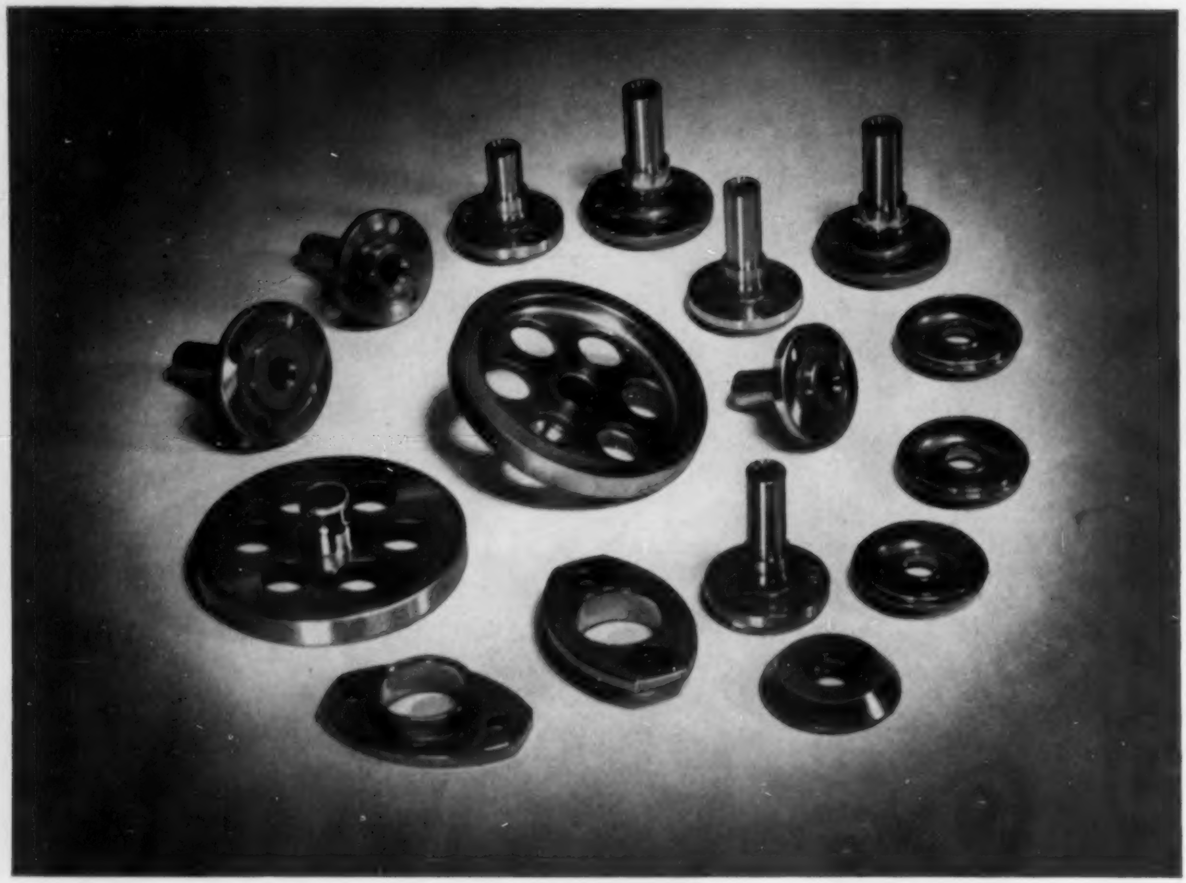
Gears, connecting rods, crankshafts and other critical forged parts are hardened in this type of furnace. Parts are heated to hardening temperature, soaked at this temperature for a controlled length of time and quenched—all automatically. Parts are also discharged automatically from the quench. This gas-fired, chain-belt, conveyor-type furnace is designed for high production, low maintenance and efficient operation—typical of all Salem-Brosius furnaces. Flexibility of time-temperature control reduces labor cost, assures product uniformity and permits variations of the heat-soak cycles.

For any heat treating job—hardening, annealing, normalizing, aging, solution heat treating, and other forms—consult Salem-Brosius for the best in furnace equipment.

SALEM-BROSIUS, INC.

CARNEGIE, PENNSYLVANIA

IN CANADA: SALEM ENGINEERING LTD. · 1525 BLOOR STREET WEST, TORONTO 9, ONTARIO



bearing manufacturer gains over 300% higher yield with Vacuum Metals FERROVAC

Because a leading manufacturer of precision instrument bearings worked to such exacting standards, he experienced an exceptionally high rate of rejection of finished parts. Then they tried Vacuum Metals FERROVAC®. . . of the same basic analysis as the air-melted grade used previously. The results were decisive. Rejections were reduced to less than 1% – a yield improvement of better than three times.

That's to be expected from vacuum-melted alloys, because of their remarkable uniformity. Gases that cause inclusions and that in turn lead to rejection – or early bearing failure – are literally sucked from vacuum-melted alloys during production . . . before the metal becomes solid.

The result is a *clean* alloy – with many of its properties improved. It is stronger, tougher, far more resistant to wear and fatigue. It works longer and harder than conventionally-melted alloy – even does the super-tough jobs where *nothing else* will work.

Only Vacuum Metals gives you one-source service – Vacuum Metals' own large organization, and its affiliation with National Research Corporation and Crucible Steel Company of America, brings you a fully integrated service. It includes everything from melting and casting, through mill rolling and nationwide distribution of finished products. If you have an application where you can use vacuum-melted metals – in experimental lots or production quantities – Vacuum Metals can serve you. Write us now, outlining your requirements. *Vacuum Metals Corporation, P. O. Box 977, Syracuse 1, New York.*

VMC

VACUUM METALS CORPORATION

Jointly owned by Crucible Steel Company of America and National Research Corporation

Personals . . .

A. F. Sprankle received the Regional Technical Meeting Award of the American Iron and Steel Institute in recognition of his outstanding technical paper on "The Effect of Deoxidation Practice and Hot Work Reduction on the Occurrence of Magnaflux Indications in E 4340 Type Steel." This paper was presented at the Philadelphia Regional Technical Meeting last fall. Mr. Sprankle is a metallurgical engineer in the steel and tube division of the Timken Roller Bearing Co., Canton, Ohio.

C. C. Mathias has been appointed area engineer in the fuel element section of the Blairsville, Pa., metals plant of Westinghouse Electric Corp. Mr. Mathias was formerly staff metallurgist in the engineering department of the New Holland Div., New Holland, Pa., of Sperry-Rand Corp.

Morris J. Sanderson has been transferred from the Hanford Atomic Products Operation of the General Electric Co., Richland, Wash., to the Commonwealth Edison Project, Atomic Power Equipment Dept. of General Electric in San Jose, Calif.

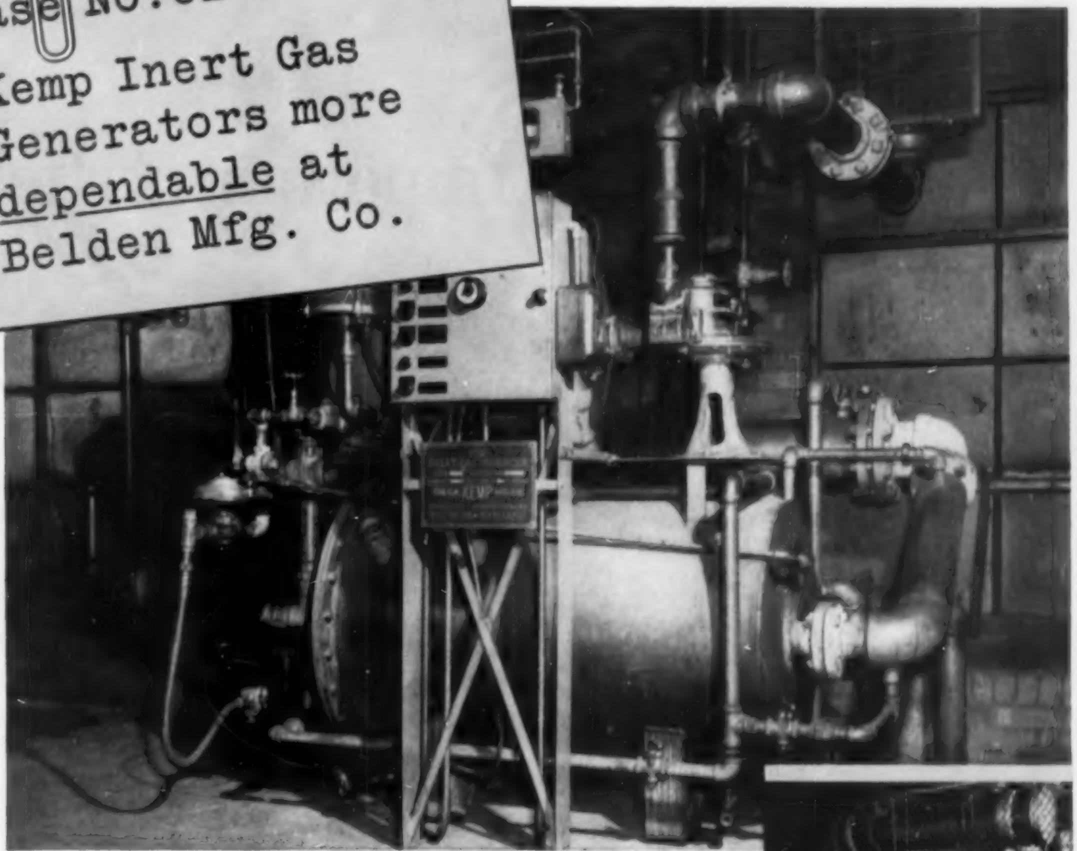
Harold Hessing has left the Navy Bureau of Aeronautics to accept a position as metallurgy liaison specialist with the advanced materials studies operation of the Special Defense Projects Dept., General Electric Co., Philadelphia.

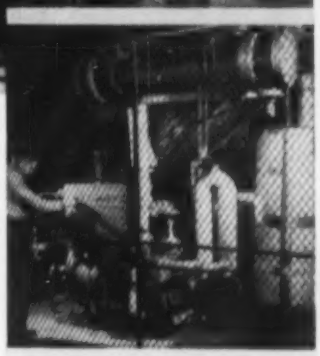
Charles M. Offenhauer has been named manager of administration of the Metals Research Laboratories, Electro Metallurgical Co., a division of Union Carbide and Carbon Corp., Niagara Falls, N. Y. Offenhauer has been associated with Electromet since 1940 and last held the post of assistant manager, research.

Horace Pops has been awarded a $500 Metal Powder Association scholarship in powder metallurgy. The Metal Powder Association established this scholarship last year to encourage engineering students to specialize in powder metallurgy in order to help fill the need for trained personnel in this field. Mr. Pops is a junior majoring in metallurgical engineering at Rensselaer Polytechnic Institute.

Case No. 61

Kemp Inert Gas Generators more dependable at Belden Mfg. Co.





Generator on first floor of plant is enclosed in wire cage to prevent tampering with controls.

How Belden utilizes two Kemp Generators in annealing copper wire

Annealing copper wire necessitates cooling in an oxygen-free atmosphere to prevent harmful oxidation. For the required protective atmosphere in this process, the Belden Mfg. Co., Chicago, Ill., generates its own inert gas. But the generating equipment formerly used by Belden did not operate reliably . . . results were erratic. So Belden installed two Model MIHE Kemp Inert Gas Generators to handle this important job.

And Kemp Handles the Job

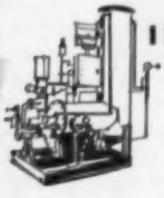
These two Kemp units assure Belden of a *dependable* inert supply. They deliver a more constant flow at the rated pressure . . . have been operating smoothly and satisfactorily since installation. Kemp's ability to produce a chemically clean inert at a *specific analysis regardless of demand* eliminates the danger of fluctuation at a critical stage.

Kemp Units Engineered for Service

Like Belden, you specify reliability when you specify Kemp. Every Kemp design includes the Kemp Industrial Carburetor for complete combustion without tinkering, without waste . . . for simplified installation and maintenance. Every Kemp design includes the very latest fire checks and safety devices. Annealing, hardening, sintering—whatever your problem, find out today how Kemp engineers can help you.

For more complete facts and technical information, write for Bulletin I-10 to: THE C. M. KEMP MFG. CO., 405 East Oliver Street, Baltimore 2, Md.

KEMP OF BALTIMORE



INERT GAS GENERATORS

CARBURETORS • BURNERS • FIRE CHECKS
METAL MELTING UNITS • ADSORPTIVE DRYERS
SINGEING EQUIPMENT

Digests of Important Articles

Welding Aluminum and Its Alloys

Digest of "Researches Into the Welding of Aluminium and Its Alloys", by W. I. Pumphrey, Aluminium Development Assoc., Research Report No. 27, 1955, 59 pages.

THE INDUSTRIAL use of aluminum and its alloys could be increased if weldability were improved. Many of these alloys are hot short, and crack during welding. Another kind of cracking occurs while the weldment is being cooled after welding. In addition, gas entrapped during welding can cause porosity and surface blisters.

Two tests are used to measure crack sensitivity of aluminum alloys. In the "ring-casting" test, the molten alloy is poured into a preheated cast iron mold to form a ring 2¾-in. OD and 1⅛-in. ID. In the "restrained-weld" test, two $0.080 \times 4 \times 5$-in. specimens are clamped in a jig and butt welded under conditions of total restraint. The latter test was designed for oxy-acetylene weldments but is also used for metal-arc and argon-arc weldments. Both tests are rated in terms of visible crack length on the surface of the specimen. Results from castings and weldments are comparable.

The factors which cause hot short cracks are related to those which cause cracks during cooling because of the stress-concentrating effect of interdenritic fissures. Such factors include everything that modifies the course of solidification. They are directly related to dendritic growth and to entrapment of eutectic phases which are controlled by:

1. Chemical composition.
2. Solidus-liquidus temperature range.
3. Welding speed, degree of superheating, thermal conductivity and rate of cooling.
4. Thermal expansion, conditions of restraint, size and shape of the specimen.

Chemical composition has a marked influence on crack sensitivity. The effect of silicon is most pronounced; crack sensitivity increases with silicon content up to approximately 0.7 to 0.8% and then decreases sharply. A similar pattern is shown by copper with the maximum at approximately 2 to 4%. Magnesium and manganese also show a fairly pronounced maximum, but changes in iron content have little effect.

Cracking in the restrained-weld test was much less when using purified argon atmospheres. Porosity and surface blisters result from (*a*) traces of hydrogen, water and hydrocarbons, (*b*) oxygen contamination exceeding 0.3% and (*c*) nitrogen contents exceeding 1%.

C. A. ZAPFFE

Springback Control in Bending

Digest of "Springback in Metal-Forming", by Federico Strasser, *Iron & Steel*, Vol. 27, June 1954, p. 235-236.

SPRINGBACK is a well-known phenomenon exhibited by most metals to varying degrees in forming or bending operations. Briefly, it is the refusal of a piece of metal to retain completely the shape given it by a forming tool (die), once pressure is released.

Springback is governed by many factors. The most important are composition and mechanical properties of the metal, thickness, and size of the inner bend radius. Secondary influences include the direction of rolling on the metal with relation to the direction of forming, die opening, setup of the forming tool, clearance and alignment, bottom position of the press-ram stroke and speed of the stroke.

It is impossible to predict the amount of springback with any degree of accuracy. An empirical method is to test any new material with an exisiting bending die that has been used for another alloy. Appearance of formed samples of the two metals gives a good measure of the "springback index" of the new material.

The common methods used to compensate for springback in bending include overbending, restriking and heating the stock. Overbending is the simplest and is used most often. The difference between the tool angle and required angle must be exactly equal to the springback angle and this can be determined only by actual trial.

Two methods have been devised for bottoming work pieces in the bending zone by overworking the metal and destroying residual elasticity. One is to shape the punch with a small projecting piece or protuberance at the inner bend radius. The other is to make the punch with a slightly smaller angle than that of the female die opening and machine a radius at the root of the die opening. This results in a slight coining of the metal in this zone. Both techniques affect the structure of the worked metal adversely.

Heating the blanks prior to bending greatly reduces springback. However, this method is slow, difficult to control precisely and is more costly than cold bending.

While right-angle bends are the most common, springback is also encountered in other types of shaping. The same corrective measures are used for square-U forming as for

Springback . . .

right-angle forming. For overbending, a standard female die is used but the punch is slightly undercut at each side. The angle of the undercut portion to the vertical should be about 20% more than the springback angle.

For all types of channel and U-forming, clearance between male and female dies should correspond exactly to the stock thickness to hold the springback to a minimum.

ARTHUR H. ALLEN

Application of Rare Earths

Digest of "The Chemical Black Sheep Go to Market", by S. Becker Treat, presented at a meeting of the Commercial Chemical Development Assoc. in May 1956.

THE RARE earths, elements No. 57 through 71, and thorium, element No. 90, have had an interesting historical interrelationship. Early in the twentieth century, about 200 companies were manufacturing mantles for gas, gasoline and kerosene lamps. These woven mantles were impregnated with a solution containing 99% thorium nitrate and 1% cerium nitrate and the only source of these salts was in Germany. When this source was lost during World War I, monazite sand was obtained from India and a plant was set up in Chicago to extract thorium and cerium. Since monazite contains about ten units of rare earths for every one of thorium and there was no market for the rare earths, thousands of tons of them went down the Chicago sewers! Eventually the demand for gas mantles diminished with the advent of electrical power. Several industries then found uses for the rare earths so the thorium was being discarded in this later era.

During World War II, the Manhattan Project absorbed the thorium not required for mantle production. In 1946 the Atomic Energy Commission announced that thorium could be made fissionable and the Brazilian and Indian governments soon placed embargoes on shipment of monazite to this country. Domestic sources in Florida and Idaho were then developed but neither is a first-class source

Rare Earths . . .

of the ore. Recently a massive deposit of monazite was uncovered in the Union of South Africa. With such a large source of thorium available, the supply of rare earths is now considerably larger than the demand.

Rare earth salts are now used in carbon arc electrodes for movie projectors and searchlights, flints for cigarette lighters, in the production of some alloy and stainless steels, in filter cloth used in the purification of bauxite, for lens polishing and for special kinds of glass. Terbium, dysprosium, holmium, erbium, thulium, ytterbium and lutecium are now being separated and their properties are being studied to determine any unusual characteristics that could be commercially important. Samarium, gadolinium and europium have neutron absorption properties of value to nuclear physicists. A thorium-zirconium-magnesium alloy is promising as a high-temperature alloy.

The problem now being faced is the marketing of rare earths. More must be known and published about these materials and the notion of "rare" must be dispelled. From a tonnage standpoint, the greatest potential user of rare earths is the steel industry. To the metallurgist, the developments in rare earths and thorium indicate the need for a reexamination of the periodic table.

J. W. Spretnak

Substructures in Ferrite

Digest of "Sub-Structures in Ferrite", by P. Samuel and A. G. Quarrell, *Journal* of the Iron and Steel Institute, Vol. 182, January 1956, p. 20-30.

Four different kinds of subcrystalline structures have been identified in ferritic iron. They are alpha veining, delta networks which delineate previous delta grain boundaries, gamma networks which trace out the former austenite grain boundaries, and a diffuse band network associated with phosphorus segregation. The authors attempt to explain alpha veining and to determine the conditions under which it appears. Armco iron and irons of somewhat higher purity were used.

Alpha veining can be revealed by etching in nital, picral or in a nital-picral mixture. The veins are continuous surface ridges which are related only to newly formed ferrite grains. Normalizing tends to preserve remnants of the gamma boundaries. The only heat treatment which removes all traces of alpha veining is recrystallization in the alpha range. Heat treatment in moist hydrogen at 1580° F. will permanently eliminate alpha veining.

There is no exact correlation between X-ray back-reflection patterns and microstructure. The diffraction patterns are similar for specimens in which alpha veining is pronounced and those in which only traces of veining are visible after prolonged etching. In each instance the diffraction spots consist of a closely grouped cluster indicating that there are a number of crystal blocks of slightly differing orientation within each grain. The recrystallized specimens with no apparent veining show more spots, due to grain refinement, but the spots are not subdivided as they should be in the absence of substructure. The X-ray and metallographic results can be reconciled if it is accepted that when only traces of veining are observed, the nital-picral etchant attacks only those subboundaries where relatively large orientation differences exist, and well-defined veining is shown up by the etch where the heat treatment has been such as to permit impurity atoms to concentrate along the subboundaries. It was concluded that recrystallization in the alpha range

Ferrite . . .

removed not the impurity but the orientation difference between crystal blocks of ferrite. Small angle boundaries can be regarded as consisting of arrays of dislocations and the effect of recrystallization would be to destroy these arrays and to sweep most of the dislocations to the new grain boundaries.

The authors conclude that:

1. Alpha veining is normally present in the structure of low-carbon irons and it may be explained in terms of a subgrain structure within the ferrite. The ease of observation depends on the presence of impurities within the metal but their removal does not affect the underlying substructure. Carbon and nitrogen are the impurities most likely to concentrate at the subgrain boundary networks and make them readily visible under the microscope. The subgrains themselves are formed as a result of plastic deformation during the gamma-to-alpha transformation.

2. Only in the absence of subgrains is alpha veining completely eliminated in the sense that it cannot be detected even by deep etching. Destruction of the subgrains occurs when more perfect grains are formed by a method, such as recrystallization in the alpha range, that does not involve the gamma-to-alpha transformation.

3. Gamma ghost boundaries are observed when there has been segregation of an impurity along the gamma boundaries and the impurity has been trapped in place by rapid cooling. It seems likely that carbon or oxygen is the element responsible.

4. The appearance of ferrite grain boundaries as surface ridges in etched microsections of low-carbon irons indicates an appreciable concentration of impurity atoms along them. Carbon appears to be responsible for this effect.

5. Much of the confusion in the literature has been caused by failure to realize that alpha veining is due to the existence of a substructure which becomes increasingly easy to detect as impurity elements concentrate along the subboundaries, and by similarity in appearance, though not in response to heat treatment, between alpha veining and the structure of partially recrystallized ferrite.

R. A. Huseby

Substitute for Wrought Nickel and Nickel-Clad Materials

Digest of "Alcoplate—a New Material for the Corrosion Engineer", by W. L. Clark, *Alco Products Review*, Vol. 5, No. 1, p. 13-19.

IN APPLICATIONS that formerly required wrought nickel or nickel-clad material, electroless nickel plate has some engineering and economic advantages. Complex shapes can be plated with a protective coating of uniform thickness and zero porosity. The plated component is less expensive than one made from wrought nickel or nickel-clad material and has the same corrosion resistance.

The electroless plating process involves a number of chemical reactions by which nickel is precipitated from a solution containing nickel sulphate, sodium hypophosphite and some special additives which prolong life and improve plate quality. The basic chemical reactions are the formation of atomic hydrogen from sodium hypophosphite plus water and the reduction of nickel sulphate by the atomic hydrogen.

If a uniform composition of plate is to be obtained the plating bath must have a constant composition during the entire plating process. Plating continues until the solution is depleted of hypophosphite ion or of its metallic cation. Consequently, the sodium hypophosphite and nickel sulphate that are consumed in the process have to be continually replenished. This is done by automatically controlled proportioning pumps in a regeneration tank.

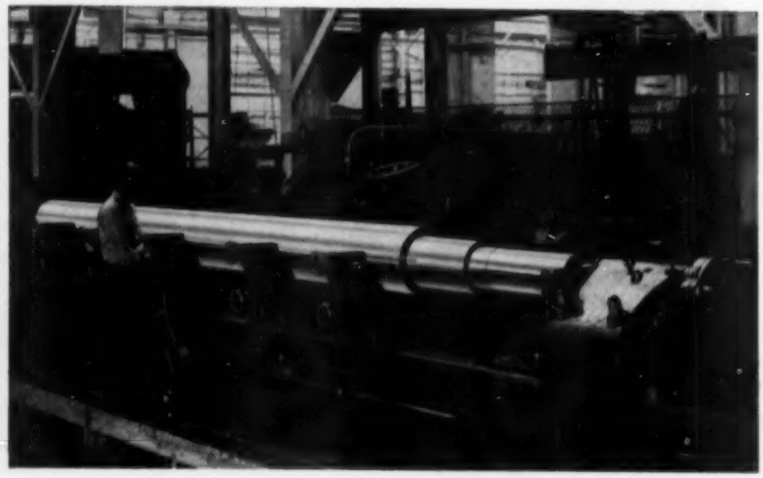
The plate has a nominal chemical composition of 91.3% Ni, 8.7% P, 0.04% C, 0.0023% O, 0.0047% N and 0.0016% H. Phosphorus content may vary from 6 to 9%. Metallographic and X-ray studies indicate that the phosphorus is present as nickel phosphide dispersed in a matrix of nickel. The as-deposited plate is assumed to be amorphous since X-ray diffraction studies fail to show any presence of a crystalline phase. The structure is unrelated to and unaffected by the structure of the underlying metal. The thickness of the coating does not affect its amorphous structure and the plate is homogeneous throughout.

Heat treatment of the plate at 750° F. results in the finest dispersion of nickel phosphide particles in the nickel solid solution. This treatment produces the highest hardness value obtainable – approximately 1100 Vickers. Heating beyond 750° F. results in lower hardness values with increased ductility and possible improvement of other properties such as resistance to impact, wear, erosion and salt spray corrosion.

The coating is free of porosity and has excellent adhesion to the base metal. The adhesive strength of the bond exceeds the shear strength of the plating. Reported values of the bond strength of electroless plate to steel range from about 30,000 to 60,000 psi.

Electroless nickel equipment has been supplied to chemical plants, oil refineries, electrical companies and aircraft manufacturers. Most of the present production is for large steel pressure vessels for Atomic Energy Commission installations.

A. COUTURE



Cracking in Mild Steel Welds

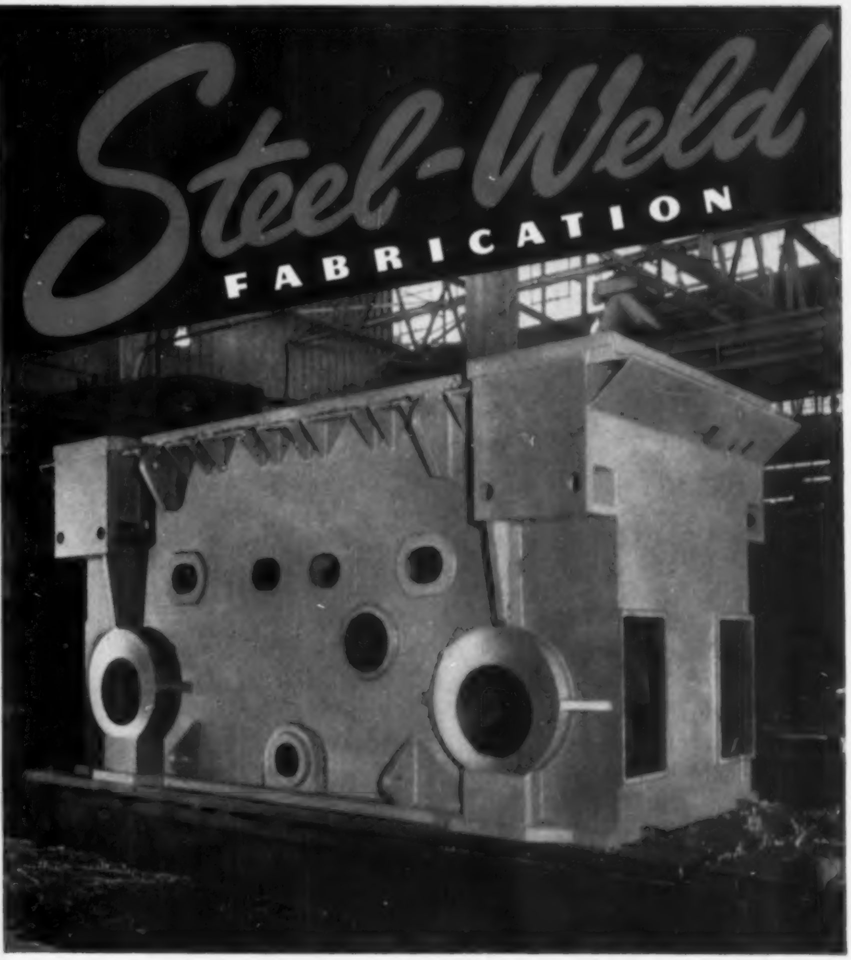
Digest of "Hydrogen in Mild Steel Weld Deposits", by N. Christensen and R. Rose, *British Welding Journal*, Vol. 2, December 1955, p. 550-558.

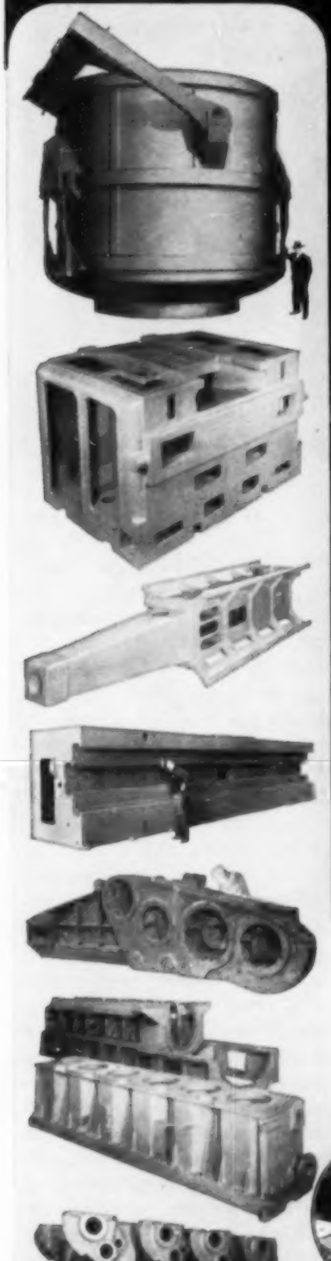
The harmful effects of dissolved hydrogen in weld metal include both general embrittlement and microfissures. Such microfissures have often been observed in E 6010 and E 6011 welds but have not been reported in welds produced with European electrodes. This article deals with the measurement of microfissures in weld metal from a number of European electrodes and with the determination of the hydrogen contents of these welds. The spatial distribution of cracks and the mechanism of crack formation were also investigated.

Electrodes of the rutile and lime-fluorspar types were chosen to represent the upper and lower extremes of hydrogen contents encountered in conventional welding. Two deep-penetration electrodes were also included. No special precautions were taken to protect electrodes from atmospheric moisture. The standard welding procedure for crack testing consisted of depositing a single bead along the center line of a piece of mild steel, 120 × 63 × 12.7 mm. Specimens for hydrogen determinations were made up of three strips, 120 × 19 × 12.7 mm. They were clamped rigidly in a vise with pieces of copper foil inserted between them so that the thermal characteristics of the composite specimen were similar to those of the crack-testing specimen. A single bead was deposited on the central strip which was unclamped and quenched in water immediately after completion of welding.

The small size and location of hydrogen cracks make them difficult to find in routine X-ray or magnetic particle inspection. A metallographic procedure adopted consisted of polishing with diamond dust, etching and repolishing for a very short time with very fine diamond dust. The etchant was a solution of hydrochloric acid, water, copper chloride and picric acid in ethyl alcohol. The cracks were counted on vertical sections through the center line of the beads in a region about 65 mm.

Steel-Weld FABRICATION





Use WELDED STEEL for Greater Strength with Less Weight!

The 50-ton weldment above is one of fifty-five identical Press Beds produced for one manufacturer of heavy presses. This piece, and the parts and assemblies illustrated at the left, are typical of thousands of Steel-Weld Fabricated units produced and machined by Mahon for manufacturers of processing machinery, machine tools, and other types of heavy mechanical equipment. Are you taking full advantage of the possibilities offered by welded steel components in your products? In the design of almost any type of heavy machinery there are pieces and sub-assemblies that can be produced more satisfactorily and more economically in welded steel —and with the additional advantages of less weight, greater rigidity and predictability. When you consider weldments, think of Mahon . . . because, you will find the Mahon organization a unique source for welded steel in any form . . . a source with complete facilities for design engineering, fabricating, machining and assembling . . . a source where design skill and advanced fabricating techniques are supplemented by craftsmanship which assures you a finer appearing product embodying every advantage of Steel-Weld Fabrication. See Sweet's Product Design File for information, or, better still, have a Mahon sales engineer call at your convenience.

THE R. C. MAHON COMPANY • Detroit 34, Michigan

Sales-Engineering Offices in Detroit, New York and Chicago

Engineers and Fabricators of Steel in Any Form for Any Purpose

MAHON

Weld Cracking . . .

from the start to about 35 mm. from the end of the bead.

There was a fairly uniform distribution of cracks across the central three-quarters of the width of the bead, with quite a sharp decrease towards the edges. The over-all crack density was much higher in the horizontal plane than in the vertical midplane section and maximum crack density was at a level slightly above the plane of the parent plate. Cracks were usually parallel to the boundaries of ferritic columnar grains and frequently cut through inclusions. Welds made with basic electrodes contained too few cracks to justify any calculation of distribution.

For the hydrogen determinations, the specimen was water quenched within one second after welding, rinsed in alcohol or ether, dried and put into a vacuum apparatus for extraction at 650° C. (1200° F.). The extracted gases were not analyzed. The results indicated that cracking does not occur with gas contents below 40 ml. per 100 g. of fused metal.

It is apparent that microcracking occurs as frequently with European electrodes as with the corresponding British or American types. Basic electrodes are practically immune to cracking. The correlation of cracking tendency with hydrogen content reported in the literature has been confirmed.

H. J. Nichols

Measurement of Machinability

Digest of "The Machining Properties of Non-Ferrous Metals", by D. F. Galloway, *Journal of the Institute of Metals*, Vol. 84, February 1956, p. 121-131.

In the symposium on shaping of nonferrous metals held in London, England, in April 1956, the problems of attaining high rates of metal removal, superior finish and longer tool life when machining the newer aluminum, titanium and Nimonic alloys were discussed. Important technical criteria in rough machining are rate and efficiency of stock removal and tool life. In finish machining the rate of surfacing, surface finish and dimensional accuracy are more important. In this paper few machinability data are given but the principles governing the adequate investigation of machining processes are outlined. These principles involve precise measurement, control and systematic variation of factors.

Measurements of cutting force are of fundamental interest and can be made with dynamometers. Composition and flow of cutting fluids and feed and speed of the tool can all be measured directly and controlled. The complex geometry of cutting tools requires careful checking with special equipment, and some optical instruments used for rapid measurement of the angles of drills and straight cutting tools are illustrated and described in detail. A special machine for control and measurement of the various factors involved in drilling is also illustrated.

Unavoidable variations in the tools or test material must be allowed for by making enough tests so that the effects of such variations will average out. In planning experiments, variation of only a single factor is not always satisfactory since interactions of two or more factors may

Machinability . . .

be important. It is better to vary several related factors in a group. For example, the effect of a change in relief angle of high speed steel drills depends on whether the steel is high in tungsten or molybdenum and possibly also on the work material and point angle.

The specific cutting force for rough machining of aluminum alloy L 64 with 0.1-in. depth of cut and 0.015-in. feed is 120,000 psi. and that for Nimonic 80 fully heat treated is 455,000 psi. Various steels have intermediate values. With lower feed and depth of cut the specific cutting force increases greatly. Friction of the chip against the tool increases the cutting force and with diamond tools the cutting force is much lower than with cemented carbide tools. The results of drilling tests are similar for rough machining; the highest values for thrust and torque are shown for Nimonic 80 and titanium alloy Ti-150 A; and the lowest for an aluminum alloy, with various steels in between. The tapping torque for titanium is about three times as great as that for an alloy steel. It is less with a sulphurized neat oil cutting fluid than with a water-base soluble oil.

In drilling, the tool life increases as the cutting speed is decreased. With logarithmic plotting the relation is approximately linear except at very slow speeds. Much better drill life is obtained on Ti-150 A with a low penetration rate due to slower speed and higher feed. Drilling tests of the same alloy with high speed steel drills indicate that for best tool life the point angle should be 105°, the relief angle 10° and the helix angle 25°.

The flank wear on cemented carbide tools is much more severe after removing 8 cu.in. of Nimonic 80 than after removing 13 cu.in. of a heat treated alloy steel under the same conditions. Cutting Nimonic for 30 min. produces about the same flank wear as 80-min. cutting of steel. In tapping Ti-150 A at 27 ft. per min. with an oil cutting compound carrying molybdenum disulphide there is a heavy build-up of titanium in the threads after only one hole is tapped. If a suspension of molybdenum disulphide in "white spirit" is baked on the tap at about


FOR
SALT
BATH
HEAT
TREATING
AJAX

Machinability . . .

400° F., more than 50 holes can be tapped without trouble.

Surface finish is affected by cutting speed, feed and the shape and composition of the tool. The relation between the finish and cutting speed is quite different for two aluminum alloys machined with carbide tools but when diamond tools are used the relation is similar for the two alloys. With faceted diamond tools, the finish varies with the orientation of the facets to the work surface and is best when a facet is parallel to the work. Although the finish deteriorates rapidly at a feed rate above 0.0015 in. per revolution with an unfavorable facet orientation of a tool, it is independent of the feed rate with the best orientation.

Machinability ratings of materials obtained from standardized tests are not considered by this author to be very useful to production engineers because the important factors of tool life, surface finish and power consumed do not bear any relation to each other and a test determines only one of them. Furthermore, tests are often made under entirely different conditions from actual machining operations. The assumption that lower cutting forces are associated with longer tool life is not justified by experience and the results of cutting-force tests are not valid criteria of machinability in general.

Drilling tests at high penetration rates are not suitable for predicting performance at normal speeds and feeds and quick machinability tests have often been misleading. It would be helpful if enough reliable machinability data could be made available to establish the validity of some of the rapid tests.

G. F. Comstock

Boron's Function in Hardening Steel

Digest of "Boron in Iron and Steel—Hardenability and Its Mechanism", by G. M. Leak, *Metal Treatment and Drop Forging*, Vol. 23, January 1956, p. 21-28.

Boron is used to improve the hardenability of steel but frequently its maximum effect is not realized. Boron increases hardenability by reducing the nucleation rate of the transformation products and the total number of nuclei formed; thus, boron delays the transformation of the metastable austenite and has essentially no effect on the kinetics of the transformation reactions.

Because the formation of ferrite from austenite requires a certain minimum energy per unit area of interface between the two phases, nucleation of this transformation product will occur at sites where part of this energy can be supplied. Nucleation occurs preferentially at grain boundaries because the elimination of an austenite grain boundary supplies to the reaction an energy per unit area of eliminated boundary. Such a source of energy is not available within a grain. The critical values for the occurrence of nucleation indicate that an energy

Boron . . .

barrier exists even at a boundary between four grains. A slight increase in the energy barrier will retard transformation by decreasing the total number of nuclei formed and by decreasing the nucleation rate of the transformation products. It has been argued that boron retards transformation by changing the energy barrier.

This theory can be extended to explain the hardenability effect in another manner. The total lattice strain energy caused by the solution of boron in austenite is reduced by the migration of these solute atoms to imperfections such as grain boundaries. Initial additions of boron to a steel will increase its hardenability because these solute atoms will migrate to the grain boundaries and lower their energy level. If boron is added in excess of the amount required to saturate the grain boundary, the extra atoms are forced into solution within the grain, thereby raising the grain-boundary energy and increasing the nucleation rate of the transformation products.

An attempt has also been made to explain the mechanism of hardenability by the solid solution hardening effect of boron. Once transformation has been initiated, the high strain energy associated with the solution of boron in austenite would oppose further formation of ferrite. Calculations have been made giving the effectiveness of boron in preventing such further transformation. The maximum efficiency of boron in delaying further transformation occurs when the ferrite is saturated with the solute atom. For saturation, the values are 1, 4 and 43 for carbon, nitrogen and boron, respectively. As the carbon content of a steel is increased, the amount of ferrite which can form is decreased. Because boron only delays the formation of ferrite, the effect of boron on complete transformation becomes less noticeable. At the eutectoid composition, cementite can be nucleated without ferrite and the effect of boron on suppressing transformation is absent.

These mechanisms depend upon knowing both the solubility of boron in steel and the manner in which it is dissolved. Existing data on the

solubility of boron in steel are somewhat conflicting. Assuming that the solubility of a solute is proportional to the volume change resulting from the solution, calculations can be made for alpha and gamma iron to find the ratios of solubilities for interstitial and substitutional solid solutions. From these calculations and solubility data, it can be inferred that boron forms a substitutional solid solution in alpha iron and an interstitial solid solution in gamma iron. Consideration of the size of the boron atom in solution and data from diffusion experiments support the conclusion for gamma iron. Data from internal friction measurements indicate that boron also forms an interstitial solid solution in alpha iron.

The mechanisms reviewed in this paper are based on the present knowledge of the extent and form of solubility of boron in steel. Selection of one of these theories and the formulation of the actual mechanism await the determination of additional fundamental data. At that time, such knowledge could be used to obtain the maximum effect of boron in improving hardenability. It is suggested that further work be conducted to determine the true nature of the solubility of boron in alpha iron. Internal friction measurements of grain-boundary relaxation could be used to determine whether boron atoms are preferentially located at grain boundaries.

G. W. Bush

Wedge Specimens Reveal Hardness Penetration in Toolsteels

Digest of "Tool Steel — Shop Metallurgical Control by a Small User", by A. J. Blackwell, *Iron & Steel*, Vol. 27, June 1954, p. 217-222.

After heat treatment, toolsteels show a considerable variation in hardness from the skin to the center. In this paper a method was sought to assess what depth of skin had to be removed to leave the ideal surface hardness on steels for drills, reamers and similar tools. In developing a toolsteel quality control system suited to the needs of a small shop engaged in manufacturing such tools, the first step was to develop a satisfactory laboratory technique and then modify it for general plant use.

Several methods can be used to measure decarburization and carbon gradients but the most accurate is a hardness survey of a prepared cross section. Since a more practical and faster technique was desired, a testing system known as "reduced diameters" was perfected. Test bars from 13 types of high speed steel were selected and rough machined in stepped diameters, with eleven successive reductions from the original hot rolled bar size. Bars ranged in original diameter from 0.457 to 0.787 in. Stock removal at the eleventh or last reduction in diameter ranged in depth from 0.043 to 0.075. A small flat was ground on each diameter to insure accuracy during hardness testing. Standard salt bath heat treat-

International Products & Mfg. Co.

switched to La Salle **fatigue-proof** STEEL BARS

TO MAINTAIN UNIFORMLY HIGH QUALITY

International Products & Manufacturing Company is now specifying "FATIGUE-PROOF" steel bars for generator and starter shafts. These are heavy-duty shafts. Formerly they used 4140 or 8640 heat-treated.

Field failures can be anticipated unless the finest of materials and the best of manufacturing practice are employed.

"FATIGUE-PROOF," by eliminating heat-treatment, does away with any possibility of quench cracked shafts getting past inspection. Since no straightening after heat-treatment is required, unfavorable residual stress due to severe straightening operations cannot be present.

It's another case where "FATIGUE-PROOF's" high strength in-the-bar eliminates a possible cause of trouble.

If you want to improve the quality of your products and avoid the problems of machining or heat-treating parts from high strength carbon or alloy steels . . try a sample bar of "FATIGUE-PROOF." If you will give us application details, send a blueprint, or call La Salle Sales Engineer at REgent 4-7800, Chicago, Illinois, he will send you a test sample if it appears "FATIGUE-PROOF" can be used to your advantage.

International Products & Manufacturing Co., of Chicago, are manufacturers of automotive starter and generator parts.

NEWLY PUBLISHED!
Get your copy of this 20-page booklet which gives detailed information on the remarkable new "FATIGUE-PROOF."

La Salle STEEL CO.
1424 150th STREET, HAMMOND, INDIANA
Manufacturers of America's Most Complete Line of Quality Cold-Finished Steel Bars

Please send me your "FATIGUE-PROOF" Bulletin.

name____________________
title____________________
company____________________
address____________________
city__________ zone_____ state________

Toolsteel . . .

ment for high speed steels was conducted on all the bars suspended on hooks.

Using a Vickers hardness testing machine with a 30-kg. load, three indentations were made on the flat of each of the 13 test samples.

Graphs were compiled to indicate hardness at increasing depths of skin removal. On similar steels a standard hardness can be insured by removing the proper amount of material as indicated from drawing the "acceptance" line of required surface hardness horizontally across the graph.

A significant feature was the rising trend of hardness with progressive reduction in diameter. The steels involved were deep hardening but the hardness trend was expected to flatten out when moving toward the center of the section. A metallographic examination showed that the amount of retained austenite varied and the carbide was dispersed unevenly in the matrix.

In the production test or modified laboratory method, a direct reading Rockwell hardness tester was used. The test sample was a 4-in. long bar for all shapes whether round, square or rectangular. On the surface of this sample a taper flat was ground from zero at one end to 0.040 in. deep at the other. To avoid grinding cracks after hardening, the bar was tapered before heat treatment.

Once the sample was prepared, testing was simple and could be passed on to routine inspection personnel. Hardness impressions were made at six equal intervals along the "wedge", starting at the full bar size. Hardness readings were plotted on a suitable scale against the depth below the originial bar skin. With this test it was easy to identify any bar decarburized during rolling or forging. Also, it was possible to determine how much metal had to be removed to obtain a specific surface hardness on production lots.

While it is useful to know at what depth below the hot rolled bar skin a particular batch of toolsteel meets quality standards, it is also pertinent to recognize why it may fail to reach such hardness values. Some production variables that affect the finished bar are:

1. Ingot casting temperature.
2. Conditions of the ingot mold.

Toolsteel . . .

3. Rate of cooling from casting temperature.

4. Furnace atmosphere for annealing ingots, billets and bars.

5. Dressing of ingot surface prior to forging.

6. Maximum hot reduction from ingot to billet.

7. Billet dressing and annealing.

8. Rolling and forging temperatures.

9. Reheating slowly between hot operations.

10. Annealing of finished bars.

Most toolsteel producers keep close observation on the above items to achieve maximum quality in the bar and forging stage. The user of toolsteels should not waste the built-in quality through lack of suitable control in heat treatment. Properly equipped preheating and hardening furnaces with accurate temperature controls are the absolute minimum.

ARTHUR H. ALLEN

Blast Furnace Construction by Welding

Digest of "A Welded Blast Furnace and Ancillary Equipment", by T. Birchall, *The Welder*, July 1955.

THE INCREASED production of British industry has made heavy demands on iron and steel producers and many blast furnaces have been put into production. Since the fabrication and erection of a blast furnace requires a considerable tonnage of steel, any saving in weight which can be introduced by changes in design or fabricating methods is of very great importance.

This article describes the fabrication and erection of a large blast furnace and its accessories where considerable savings in weight were realized by use of welding wherever practicable. The furnace has a hearth diameter of 21 ft. and is designed to produce 3500 to 4500 tons of pig iron per week. The steelwork and machinery were erected in 13 months.

The furnace columns and lintel were fabricated by welding. The length of the column had to be exact and free from distortion. Seven pieces were assembled by welding to form the lintel which had to be level and form a true circle with an outer diameter of 38 ft. It is significant that the parts of the furnace where precision and freedom from distortion are of the utmost importance were fabricated entirely by welding.

Welding was also used in the fabrication and erection of the hot blast stoves which were each over 22 ft. in diameter and 110 ft. high. The gas cleaning plant was also of all-welded construction; the main structures were the precoolers and three electrostatic precipitators. Welding was used wherever possible in the construction of the ore and coke bunkers, handrails, the cast house, overhead crane and valve bodies.

Radioactive isotopes were used to control the quality of the weldments. A mobile unit visited the site every four to six weeks. All the films were developed on the site and the welders were allowed to see the radiographs of their own work. This was found to encourage them to turn out high-quality work.

This paper contains a great deal

Blast Furnace . . .

of detail on the welding methods that were used. However, the most important fact is that it was possible to develop practical methods that could be used to erect such large structures with the required degree of precision.

R. C. SHNAY

Case Hardening Accelerated by Cyclic Stresses

Digest of "The Effects of Cyclic Stressing Upon Diffusion in Plain Carbon Steels", by H. Schenck and E. Schmidtmann, *Archiv für das Eisenhüttenwesen*, Vol. 25, November 1954, p. 579-583.

RATES of diffusion govern the time required for surface treatment of steels and the transformation and precipitation processes which occur in the solid state. The rates can be changed by the application of stress and in this paper the effect of cyclic stressing upon the carburizing, nitriding and chromizing of a rimmed basic bessemer steel is evaluated.

The carburizing experiments were carried out in a mixture of 60% finely ground charcoal and 40% barium carbonate. Case depth was determined by microscopic examination, microhardness traverses and chemical analyses of successive 0.1-mm. thick layers.

Comparison between specimens pulsated at 0.2% strain and unstressed specimens carburized at 1650 and 1740° F. revealed a marked increase in case depth in the stressed steel. The percentage increase in case depth is greater at the lower temperature and the carbon content at the same depth is greater in the stressed than unstressed specimens.

The effect of static deformation before and during carburizing was also studied. Some specimens were elongated 2% before the start of the cycling and others were elongated after one hour of carburizing under the alternating 0.2% strain and then the cycling was continued. Deformation before cycling produces no effect. The variation of microhardness with depth for the specimen stretched during carburizing differs considerably from the normal varia-

XVI

This is the sixteenth of a series of advertisements dealing with basic facts about alloy steels. Though much of the information is elementary, we believe it will be of interest to many in this field, including men of broad experience who may find it useful to review fundamentals from time to time.

Copper: Its Principal Effects in Alloy Steels

One of the best known of all metals, copper certainly needs no introduction here. Its uses are legion. It is one of the best conductors of heat and electricity. It is popular with the housewife, essential to the engineer. But possibly not so well known is its very important function as an alloying element in certain types of steels. So used, copper increases resistance to atmospheric corrosion and also acts as a strengthening agent.

Since copper does not oxidize in the steel melt, it can be added at any time during the course of the heat. Pure copper melts at about 1980 deg F.

Copper is added to steel in varying amounts. The actual proportion, of course, depends upon the end product in mind. Some of the most widely used copper-bearing steels are those containing from 0.20 to 0.50 pct. In these, copper has been found to increase corrosion-resistance without materially affecting mechanical properties. It has been found, too, that paint frequently lasts longer on such steels than on the non-copper-bearing types.

Among the best known of the copper-bearing steels are the high-strength, low-alloy grades developed in recent years. Generally speaking, the ductility of steels in this group is comparable to that of conventional structural steel. The yield strength, however, is usually higher. Copper, working as a team with chromium, nickel, and phosphorus, substantially raises the level of corrosion-resistance in these steels; yet its presence does not adversely affect welding characteristics.

Copper-bearing steels are a subject in themselves, a subject in which Bethlehem metallurgists are well versed. If you would care to know more about this interesting group of steels, feel free to consult with our technicians. They will gladly work closely with you and help with any problems you may encounter. And please remember, too, when you need alloy steels of any kind, that Bethlehem manufactures the full range of AISI standard alloy grades, as well as special-analysis steels and all carbon grades.

If you would like reprints of this entire series of advertisements, Nos. I through XVI, please write to us, addressing your request to Publications Dept., Bethlehem Steel Company, Bethlehem, Pa. The material is now available in a convenient 32-page booklet, and we shall be very glad to send you a free copy.

BETHLEHEM STEEL COMPANY
BETHLEHEM, PA.

On the Pacific Coast Bethlehem products are sold by Bethlehem Pacific Coast Steel Corporation. *Export Distributor:* Bethlehem Steel Export Corporation

BETHLEHEM STEEL

Case Hardening . . .

tion and resembles the curve for a specimen carburized under a cyclic stress producing 1% permanent deformation. In the latter the surface hardness is lower and the fall of hardness toward the core more gradual. The results indicate that a permanent deformation accelerates the diffusion of the carbon towards the core and prevents its build-up at the surface.

In order to determine whether the jolting of the specimen, which promotes more intimate contact between the carburizer and specimen, was not the major factor in increasing the case depth, box-carburized specimens were pulsated at 1740° F. This treatment reduced the case hardness and reduced the difference in carbon content between the case and core. Specimens subjected to ultrasonic vibrations during carburizing had a greater case depth and a higher carbon content in the case than was produced by cyclic straining 0.2%. Since the elastic deformation produced by the ultrasonic generator was smaller than that produced mechanically it seems that it is the total energy input that exerts the decisive influence on carbon diffusion. Metallographic examination of pulsated specimens suggests that the diffusion occurs principally along the grain boundaries.

The effect of cyclic stressing on nitriding was studied and it was found that the depth of the nitrided case increases as the amount of elastic deformation increases.

The rate of diffusion of chromium into the steel was measured on chromized and chromium-plated specimens. Penetration of chromium in the absence of cyclic stressing was negligible but was appreciable in the stressed specimen. The chromium diffusion zone was followed by a zone enriched in carbon and then a zone low in carbon. Cyclic stressing destroyed the chromium plate so that only small amounts remained on the specimens.

The authors give no theoretical discussion of their results but the work does establish that cyclic stressing accelerates the diffusion of carbon, nitrogen and chromium. The frequency as well as the amplitude of cyclic straining is important.

W. A. Morgan

Metal Progress

Bulletin Board...

The Buyers Guide For Metals Engineers

READERS' INFO-COUPON SERVICE, METAL PROGRESS
7301 Euclid Avenue, Cleveland 3, Ohio

Please send further information, as checked at the right, on the advertisements in the Bulletin Board with numbers I have listed below—

(Bulletin Board Item Number)	Send Catalog or Engineering Data	Send Price Info	Nearest Source of Supply
	☐	☐	☐
	☐	☐	☐
	☐	☐	☐
	☐	☐	☐
	☐	☐	☐

(Please check)

Your Name...Title.................

Company...

Street...

City...Zone........State.................

Brittleness in Copper-Antimony Alloys

Digest of "The Intergranular Brittleness of Single-Phase Copper-Antimony Alloys", by L. M. T. Hopkins, *Journal* of the Institute of Metals, Vol. 84, February 1956, p. 102-108.

COPPER-ANTIMONY ALLOYS show intergranular brittleness at low temperatures but become tough as the temperature is raised, the transition temperature increasing with antimony content. No precipitated phase is visible but there is a faint grain-boundary film which has been attributed to "equilibrium segregation" resulting from the great difference in size between the copper and antimony atoms. This investigation was undertaken to determine if the brittle-to-ductile transition could be obtained after treatments that would be entirely within the single-phase region of the equilibrium diagram.

Seven alloys made from electrolytic metals and containing between 0.9 and 2.5% antimony were employed. Standard Charpy impact specimens were machined from hot rolled ⅝-in. diameter rods and tensile specimens were obtained from material machined to ⅜ in. diameter and cold swaged to ¼ in. diameter. The impact specimens were heat treated at 1290° F. and either slowly cooled at 18° F. per hr. or quenched in water, oil or lead.

The alloys were brittle and required little energy to cause failure at both high and low temperatures but at some intermediate temperature the ductility increased. The temperature at which maximum ductility occurred was independent of composition although its value decreased with increasing antimony content. The slowly cooled test samples required smaller energies to produce failure at both high and low temperatures than the quenched samples. The losses in impact strength due to high and low-temperature brittleness and the changes brought about by altering the cooling rate took place at temperatures at which all of the antimony should have been in solid solution.

The alloys showed sharp yield points at all test temperatures from –320 to 930° F. At some temperatures, there were indications of strain aging during the test. The tensile tests were used to measure the effects of composition, rate of straining, rate of cooling and grain size on the tensile properties. The reduction in area values indicated that these alloys are brittle at both low and high temperatures but are ductile in the intermediate temperature range. The mean temperature of the ductile range is relatively unaffected by composition or grain size but is lowered by a decrease in the strain rate. Quenching from the annealing temperature decreased the low-temperature brittleness, but did not affect the high-temperature brittleness. The brittle samples at both high and low temperatures exhibited intergranular fractures.

The tensile strengths of the alloys generally decreased as the test temperature was increased, but at intermediate temperatures a plateau or peak occurred which corresponded to the beginning of the marked fall in ductility. Indications of strain

Cu-Sb Alloys . . .

aging first appear at the temperature of this plateau or peak. From the tensile tests made at various speeds the apparent activation energy for strain aging in the 1.7% antimony alloy was 28,300 cal. per mole.

Microscopic examination of failed samples did not reveal a precipitate even under the electron microscope although grain-boundary grooves were visible. Low-temperature brittleness was found to be accompanied by little intergranular cracking except for the fracture itself, whereas in the test pieces fractured at high temperatures, many intergranular cracks occurred which were well removed from the failure.

The low-temperature brittleness begins at temperatures where the structure consists entirely of a single phase. The presence of a yield point in the most dilute alloy shows that there is marked segregation of antimony in the disturbed atomic structure. It is reasonable to believe that equilibrium segregation at the grain boundaries in these alloys occurs at all temperatures. Both low and high-temperature embrittlement occurs in the presence of equilibrium segregation, but it is unlikely that this segregation is the cause of embrittlement.

It is suggested that low-temperature brittleness is influenced by stress concentrations set up at the end of slip planes. High-temperature brittleness possibly occurs in the presence of excess vacancies.

R. F. Hartmann

Factors Affecting Extrusion Force

Digest of "The Present Position of Impact Extrusion Technique," by Robert Chopin, presented at the Joint Metallurgical Societies meeting in France, June 1955.

The relationship between the extrusion force required during each stage of the reverse impact extrusion process and the energy absorbed by the workpiece has been studied at the Centre Technique de l'Aluminium in France to determine the capabilities of the process. The initial tests were conducted on 99.5% aluminum extrusions 60.5 mm. in diameter with wall thickness of 0.75 mm. formed on a hydraulic press.

Several distinct steps are apparent from records of instantaneous pressure. Because the entire cycle is completed in less than 0.4 sec., the variation in pressure cannot usually be observed. The pressure builds up initially to some critical value at which the material begins to move. At this point the pressure drops suddenly and this release of pressure is sometimes accompanied by a noise like an explosion. The alternating increase and sudden release of pressure is repeated until the extrusion is completed.

If all the energy expended in forming an extrusion is assumed to have been used to heat the workpiece, the temperature increase of the extrusion could not exceed about 310° F. If all this heat were absorbed by the walls of the extrusion, the temperature increase could not be more than about 380° F. so temporory fusion cannot occur.

Tests conducted on a 600-ton mechanical press indicated that maximum extrusion force is independent of the bottom thickness when thickness exceeds a minimum

Extrusion . . .

value of about 1 mm. The force increases with increase in initial slug thickness but varies nonlinearly with change in wall thickness.

Brinell hardness seems to give a more accurate indication of the force required for extrusion than any other mechanical property. For light alloys, there is practically a linear relationship between Brinell hardness number and extrusion force for a specific extrusion ratio and slug thickness.

The results of the laboratory investigation have indicated the possibility of making asymmetric extrusions. A rectangular extrusion 50×30 mm. has been produced with a wall thickness of 0.22 mm. on the long sides and 0.29 mm. on the short sides. Its height was 300 mm. which was the maximum capacity of the tools available.

C. O. Smith

Notched-Bar Properties of Ship Plate

Digest of "Investigation of Influence of Deoxidation and Chemical Composition on Notched-Bar Properties of Ship Plate Steels", by F. W. Boulger, R. H. Frazier and C. H. Lorig, *Welding Research Council*, Bulletin No. 26, April 1956, 18 p.

This investigation of the effect of small changes in composition on the impact properties of semikilled steels was undertaken to learn more about the fracture characteristics of ship plate steel. About 400 steels of two different base compositions were used. One was similar to the composition of A.B.S. Grade A steel, the alloy used in ships during World War II. The other base composition was similar to that of A.B.S. Grade B steel.

The transition temperatures of the steels were determined with keyhole Charpy and Navy tear tests. The criterion for the Charpy transition temperature was taken as the temperature where the average energy value was either 12 or 20 ft-lb. It was found that by using either energy level, the same general conclusions regarding the ductile to brittle transition of the steels were obtained. The 12-ft-lb. transition temperature

Ship Plate . . .

was more discriminating for steels which fracture at room temperature with comparatively little deformation. The transition temperature in the tear test was taken as the temperature where the probability of brittle fracture was the same as the probability of ductile fracture. For this purpose tear-test specimens which developed a fracture area less than 50% fibrous were classified as brittle.

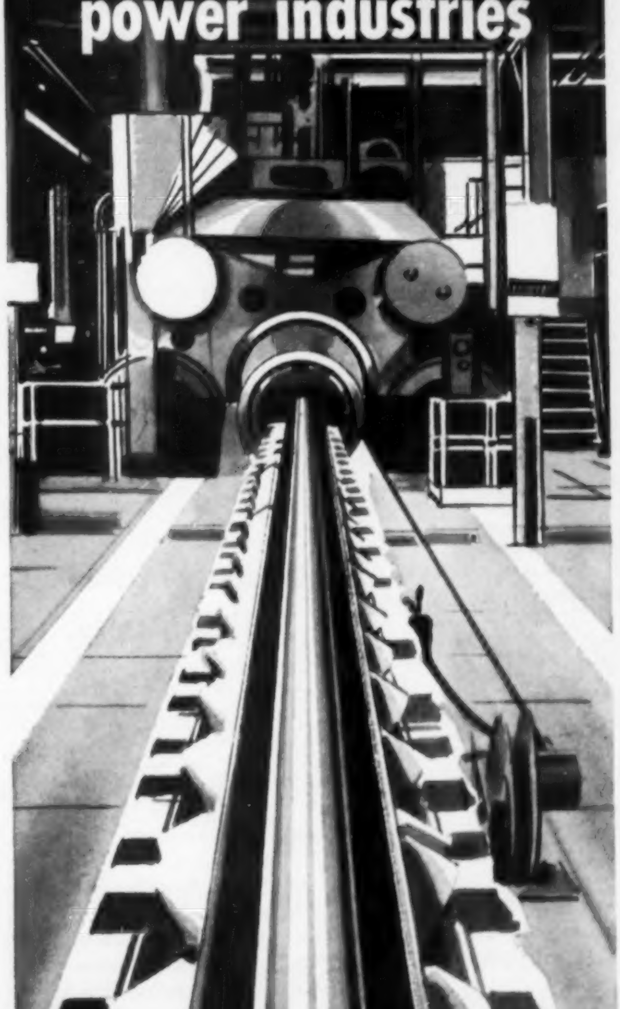
A decrease in carbon content or an increase in manganese content lowers the transition temperature. The effectiveness of manganese additions decreases at high manganese levels. To determine whether brittle cracks would propagate at lower stresses in the low-carbon alloys, the authors tested steels using the Standard Oil Development test. The results indicated that a reduction in carbon content may actually increase the stress required for brittle fracture and that the manganese content had little influence on this property.

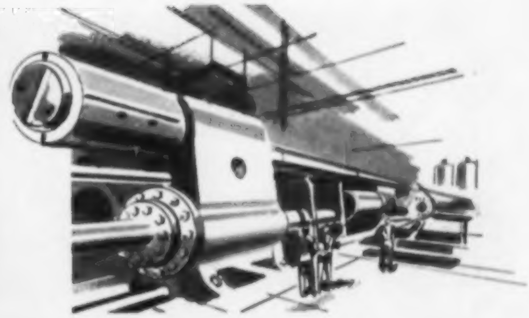
Phosphorus and nitrogen additions raise the transition temperature but sulphur content in the range from 0.023 to 0.050% has no appreciable effect. An increase in silicon content in the range from 0.01 to 0.20% lowers the transition temperature. Above 0.20%, the effect of silicon variation appears to depend upon the carbon, manganese and aluminum contents and the type of test.

To evaluate the effect of aluminum, 51 heats of steels containing 0.10% silicon or less were tested. The transition temperatures decreased as the aluminum content was increased to 0.25%, but in one instance a steel containing 0.27% aluminum gave a higher transition temperature. The authors offered no explanation for this behavior. An important finding of this part of the investigation was that the reduction in the transition temperature varied with the silicon content. The addition of aluminum is most effective in steels containing 0.01% silicon. The smallest reduction in transition temperature was found with steels containing 0.10% silicon.

Other alloying additions were also studied and it was found that they did not affect the transition temperature if present in small amounts. The effect is negligible if titanium is less than about 0.08%, vanadium and molybdenum less than 0.10% and

For longer life, higher performance in the petroleum, chemical and power industries





Corrosion-Resistant, Heat-Resistant EXTRUDED Steel Pipe

Curtiss-Wright's Metals Processing Division now offers the petroleum, petrochemical and power industries a line of high-quality, extruded steel tubular products to meet the most severe demands of modern processing. Inherent corrosion and heat-resistant properties of the steel alloys used are amplified by extrusion because the finished tube is produced with only one heat, in one pass of the giant 12,000 ton press . . . formed under compression in a matter of seconds without seams, in lengths up to 50 feet. Extra margins of resistance to corrosion and heat are built in easily by extruding heavier pipe wall thicknesses at no sacrifice in production speed. The most up-to-date quality control facilities, including ULTRASONIC TESTING, are employed in production.

Curtiss-Wright's extrusion facility is a specialty mill, ideally equipped for the production of special purpose, premium quality tubing. Conformance to A.S.T.M. specifications and other exacting standards is assured by an experienced engineering staff and the most modern metallurgical testing equipment.

When higher pressures and temperatures, or more corrosive service conditions demand more than the ordinary in large diameter pipe, let Curtiss-Wright serve you through the nearest Metals Processing Division Branch Office, or write to the Main Office address shown below.

78 Grider Street, Buffalo, New York

METALS PROCESSING DIVISION

CURTISS-WRIGHT

CORPORATION • BUFFALO, NEW YORK

ELECTRONICS • NUCLEONICS • PLASTICS • METALLURGY • ULTRASONICS • AVIATION

Ship Plate . . .

zirconium less than 0.04%. The Charpy test indicated that larger quantities of zirconium may be beneficial.

Reducing the temperature of the final hot rolling pass generally lowered the notched-bar transition temperatures of semikilled steels. The A.B.S. Class A steels rolled in commercial mills showed this consistently but data for 13 commercial Class B ship plates were inconclusive. Plates cooled from 1600 to 1700° F. in air had small ferrite grains and in these steels the transition temperature was decreased about 30° F. for a reduction in grain size of one A.S.T.M. number. Samples which were austenitized at 1800 or 1900° F. had coarser ferrite grains and their transition temperature was higher.

The complete data indicate that normalizing from temperatures around 1650° F. can reduce the transition temperatures of ship plate and the reduction expected can be estimated from the change in ferrite grain size produced by heat treatment. The change in grain size depends on the finishing temperature during rolling, the rate of cooling from the finishing temperature, plate thickness, composition of the steel and normalizing treatment.

W. A. Morgan

Evaluation of Cumulative Fatigue Damage

Digest of "Cumulative Fatigue Damage of Axially Loaded Alclad 75 S-T 6 and Alclad 24 S-T 3 Aluminum-Alloy Sheet", by Ira Smith, Darnley M. Howard and Frank C. Smith, National Advisory Committee for Aeronautics, Technical Note 3293, September 1955.

A method of assessing fatigue damage under varying stress levels during cyclic loading is extremely important because very few service applications are at constant stress levels. In 1945 M. A. Miner proposed a cumulative damage concept which stated that if a specimen would fail under a given stress pattern in N cycles, the fatigue damage at n cycles is n/N fraction of total failure. Therefore, if a specimen is loaded cyclically under a number of different stress

Plan Now to Attend a New Kind of ASM Technical Session

Discussion Forum on

Die Wear and Die Life in Stamping Operations

under the general chairmanship of

Paul G. Nelson
The Budd Co.

Thursday morning and afternoon, October 11, 1956
at Cleveland Public Auditorium
38th National Metal Congress and Exposition

Purposes:

To exchange ideas and experiences on die wear and life.

To attempt agreement on uniform methods of recording data on die wear and die life for developing further information on die performance, leading to organized cataloging of experience.

Three Discussion Groups:

1. Minimizing Die Wear by Die Design.
2. Minimizing Die Wear by Part Design.
3. Effect of Press Speed on Die Life.

Each of the groups will be divided into tables of ten participants to discuss its subject informally. All groups will reconvene after lunch and listen to condensed reports on each of the smaller discussions. By this method the specific problems and questions of a majority of the members of the audience can be considered, and areas of agreement and disagreement of the total group can be summarized.

Fill in the attached coupon now, indicating your interest in joining one of the discussion groups on October 11.

Discussion Forum Staff
American Society for Metals
7301 Euclid Ave., Cleveland 3, Ohio

Please send further information and... application forms concerning the Discussion Forum on Die Wear and Die Life in Stamping Operations.

Name ....

Title ....

Company ....

Address ....

City & State ....

Fatigue . . .

conditions, the total damage is the sum of the individual n/N values and is equal to a factor, D. If Miner's concept holds, D will equal one at failure.

A great deal of research has been conducted on the effects on D values of various stress and cycle patterns. Most of the work has been done on steels. The work reported in this paper concerns itself with two aluminum alloys, 2024 and 7075. Only two stress levels were used in any one test, applied in complete reversal. In some tests the high stress level was used during the first portion of the test for a predetermined number of cycles; in others the low stress level was used first. Specimens were usually run to failure at the second stress level. In a few tests short series of cycles at very high stresses were applied first and then the test was run to failure at the lower stress level.

Tests at stress level combinations of 30,000 and 60,000 psi. yielded D values between 0.805 and 0.879 when the low stress was applied first and 0.729 to 0.896 when the high stress was applied first. The differences between the two sets of D values are probably not important but the values suggest that the dual-stress test damages specimens faster than a simpler single-stress test. The importance of this minor reduction in D value is probably slight.

Some values for D over 1 were obtained in a series of tests designed to explore the effect of "prior dynamic stressing", which means application for a few cycles, of stresses high enough to produce some yielding. Some of the tests produced average D values as high as 1.44. When the low stress level was applied first, no pattern of variations in D values developed.

The data indicate that fatigue life of either of the alloys, in 0.032 and 0.064-in. sheet, can be predicted from Miner's cumulative damage ratio within 20% for at least 72% of the tests and within 10% for 40% of the tests. The value of the damage ratio, D, in predicting fatigue life in dual-stress tests was found to be unimpaired by choice of stress amplitude or mean stress.

M. W. Mote

Gear Tooth Wear

Digest of "Measuring Gear Tooth Wear", by George Uberti, *Journal* of American Society for Naval Engineers, Vol. 68, February 1946, p. 151-153.

Greater hardness and improved finish of gear teeth will permit stress increase or size reduction for a given application. Both are necessary in gears designed for minimum size and weight without sacrifice in reliability. To obtain better gear performance, extensive tests of conventional and advanced types of ship main reduction gears are conducted at the U.S. Naval Boiler and Turbine Laboratory. The quantities measured after test runs include tooth involute profile and helix angle, tooth spacing, circular and normal pitch. Standard commercial measuring machines are employed for most sizes of main propulsion gears.

Tooth wear (that is, the difference in thickness before and after operation) is a more difficult quantity to determine. Standard commercial measuring machines measure variations and deviations rather than absolute changes. Gear tooth vernier calipers measure only in units of 0.001 in. but tooth wear is in the order of 0.0001 in. and requires a more precise instrument for meaningful measurements.

A device to make such measurements incorporates three micrometers arranged to position a measuring finger which contacts a 0.0001-in. dial indicator. Thickness can be measured at any desired depth by turning the micrometers to a predetermined setting. After adjusting for proper thickness and depth, the zero setting is obtained by inserting gage blocks of the thickness specified for the gear tooth between the finger and frame, and setting the dial to zero. The dial then reads deviation in 0.0001-in. increments from the specified thickness. This technique allows determination of tooth wear except at the ends of the tooth where wear has a somewhat greater significance.

Routine gear inspections include a series of profile checks taken along the tooth length.

Repetition of these measurements after operation of the gears allows detection of shape changes includ-

Gear Tooth Wear . . .

ing such things as tooth end loading, rounding of tips, root interference and other signs of nonuniform wear. No indication is given of the amount of wear between successive readings. If, however, the absolute wear is determined at any point, it is possible to deduce the amount of wear at any other point through which a profile or helix angle check is made. By combining the results of profile checks and absolute thickness measurements, it is possible to determine a two-dimensional plot of the wear over the surface of a gear tooth including the tooth ends.

C. O. Smith

Rubber Forming Nonferrous Alloys

Digest of "Rubber Pressing", by J. Fielding, *Journal* of the Institute of Metals, Vol. 84, February 1956, p. 147-159.

Nonferrous aircraft parts which are needed in small quantities are often formed with rubber punches. The only equipment required is a female die, a press and a block of a special kind of hard rubber.

Most dies used for aluminum are made of a paper-base synthetic resin called "Delaron" which is hard yet easily machined, although either plywood or a zinc alloy could be used. Aluminum alloy parts are usually formed within 2 hr. after solution heat treatment, when ductility is high. There is then only 4 to 5° springback from a 90° bend, whereas in the aged condition, springback would be 8 to 12° for the same bend.

To estimate the maximum permissible deformation, the minimum bend radius is determined and converted to a corresponding value of percent stretch. For bend angles below 80° the actual maximum stretch is less than the theoretical because deformation is spread over a larger area than just at the bend.

The aluminum alloy commonly used in Great Britain is L 72 containing copper, magnesium, silicon and manganese. When this alloy is solution treated, flanges 2 to 4 in. in length can be stretched up to 42%; those 6 in. or longer can be stretched to a maximum of 30%. For a concave

Rubber Forming . . .

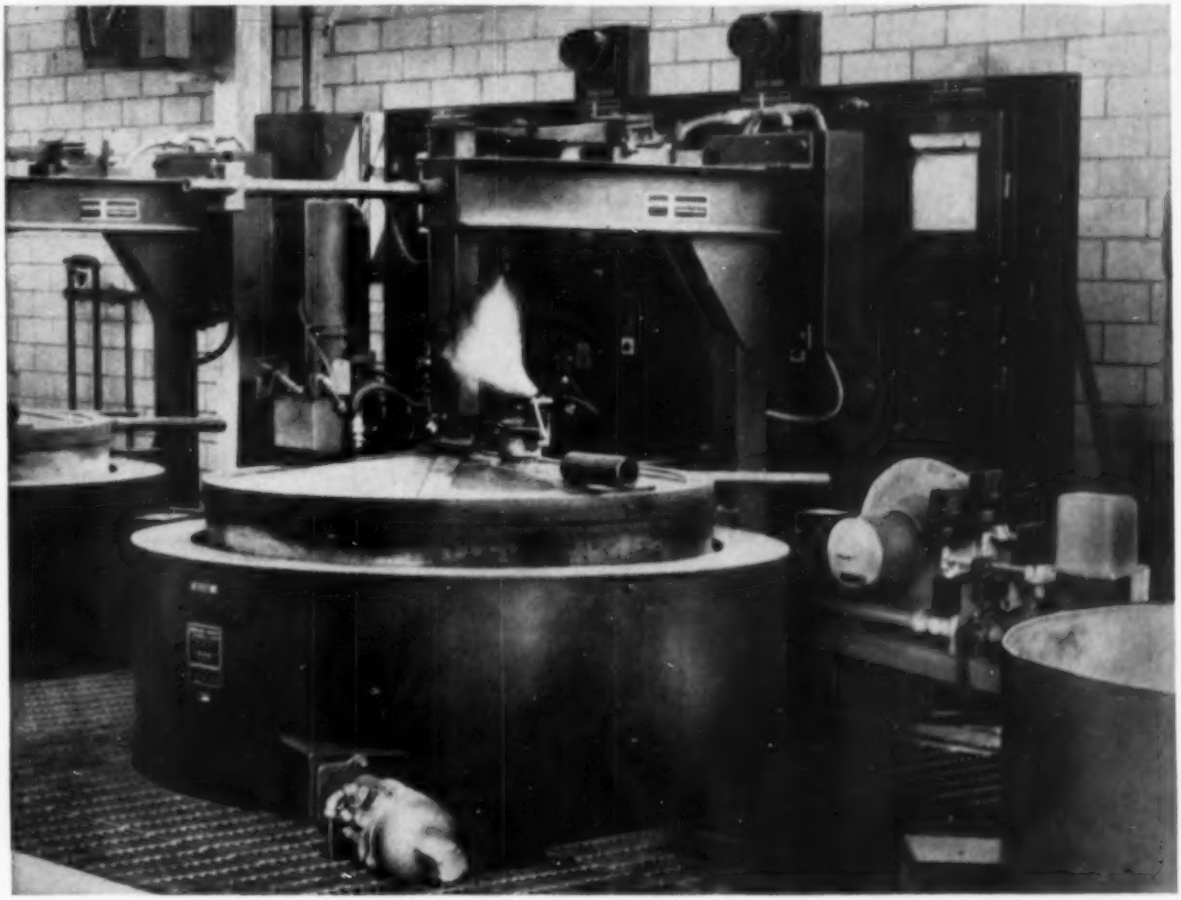
curved flange, the maximum strain is found only at the middle of the curve with the strain decreasing to zero at the ends. In stretch flanges the springback is about 1 to 3°.

It is difficult to avoid wrinkles in rubber-forming convex curved flanges. The maximum shrink possible without wrinkles is normally 2 to 3%. In sheets 0.05 to 0.06 in. thick the wrinkles formed in shrinking up to 5% can be removed by handwork. Wrinkling can be minimized by using harder rubber and higher pressures. Other helpful techniques include (*a*) guiding the edge of the blank with a "slipper block", (*b*) dividing the curved flange to be shrunk into a number of short segments, (*c*) providing recesses in the die for excess metal from the shrunk flange, (*d*) using steel pressure plates and draw plates for ironing out wrinkles, and (*e*) smoothing the wrinkles by hand soon after pressing.

Magnesium alloys can be cold drawn only lightly without cracking, and rubber forming has been used occasionally at room temperature. In such work the springback is large and variable, there is considerable residual stress and fine cracks are difficult to detect. The 1.5% Mn alloy is the most suitable for cold forming. The minimum bend radius is eight times the sheet thickness, and the maximum permissible stretch in flanges is 5 to 7%. Flanges that require shrinking give excessive trouble from wrinkles and springback. Stress-relieving for 30 min. at about 360° F. is necessary for all cold formed magnesium alloys.

For hot pressing of magnesium a 1-in. layer of heat resistant rubber is used as a facing over a natural rubber pad. Such facings will last for about 1000 pressed parts. The most satisfactory temperature for forming is 500 to 610° F., with an 80-sec. delay between removal from the furnace and actual pressing of the sheet. The dies are heated so that the hot sheet will not cool too rapidly. Plastics and zinc cannot be used for dies but cast iron, aluminum, or magnesium alloys are practical. Scrap aluminum castings are cheapest and last longer in service.

In hot formed magnesium flanges a stretch of 75% is possible. Here,



Rubber Forming . . .

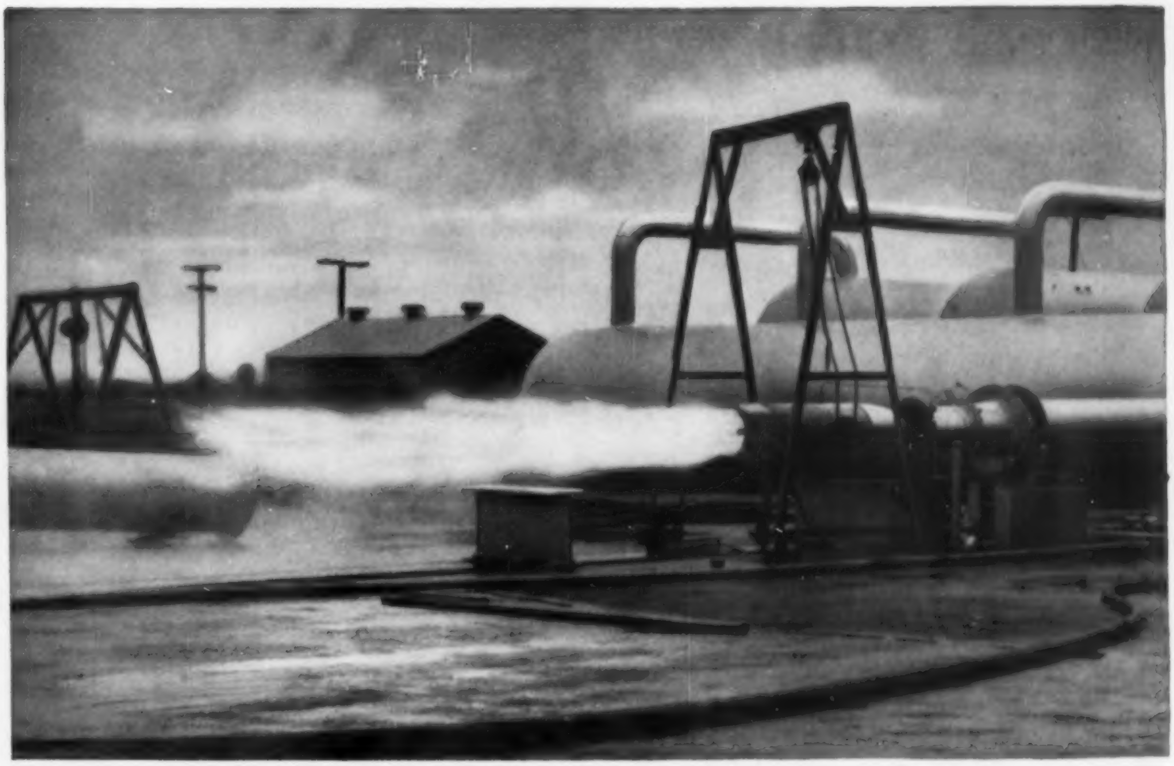
springback is negligible. Bend radii of 1 to 2 times the sheet thickness are practical. For hot formed shrink flanges, the maximum possible shrink without wrinkling is 5 to 9%. Magnesium can be formed hot more easily than aluminum can cold but greater care is required.

The forming behavior of wrought titanium is similar to that of the magnesium alloys. The commercially pure titanium sheets used for rubber pressing have about 56,000 to 89,600 psi. tensile strength, 40,300 to 82,900 yield strength and 15 to 20% elongation. Titanium formed slowly at room temperature has considerable springback and high internal stress. The springback is about 7 to 15° for sheets 0.015 in. thick and 6 to 12° for sheets 0.041 in. thick. Forming curved flanges cold requires high pressure because of the strength of titanium. Rubber pressing of stretch flanges in sheets less than 0.036 in. thick is possible when no more than 30 to 40% deformation is required. Stress-relieving for 10 to 30 min. at 930° F. is necessary after forming. Shrink flanges cannot be formed cold because of wrinkles.

Titanium can be formed better hot than cold. Less pressure is required and there is less springback. The most suitable temperature is 570° F. Heat resistant rubber is used but its service life is short because of the high pressure required. The dies can be made from either a magnesium alloy or mild steel. The minimum radius for hot bending is equal to about half the sheet thickness. Springback is 1° or less with the minimum bend radius. Stretch flanges may be formed hot without cracking even up to a 50% stretch. For shrinkage flanges 6 in. long, curved to a 6-in. radius, in sheets 0.015 to 0.028 in. thick, the maximum shrink without wrinkles is 3%. The discoloration caused by heating titanium to 570° F. is removed by pickling 10 to 15 min. in a water solution containing 40% HNO_3 and 2% HF at 150° F.

Titanium sheets up to 0.036 in. thick can be formed by hot rubber pressing with the same equipment and the same practice as used for the magnesium alloys.

G. F. Comstock



Ramjet tailpipes withstand severe abuse. (*Photo courtesy Marquardt Aircraft Company*)

MULTIMET Alloy Controls the Blast of Ramjet Engines

Tailpipes used to direct the searing blast of power in today's ramjet engines must withstand temperatures in excess of 2000 deg. F, plus severe vibration. High-speed ramjets operate in the neighborhood of 1500 mph. At these high speeds, vibration is almost as serious a threat to tailpipe life as heat. Because of its strength at high temperatures, MULTIMET alloy has given good service in tailpipes that vibrate as much as three inches.

Ramjet tailpipes are made of MULTIMET alloy sheet that is only 0.051 to 0.078 in. thick. The combined high-temperature strength and oxidation resistance of MULTIMET alloy permits the use of lightweight tailpipes with good heat-transfer properties.

MULTIMET alloy is one of many HAYNES alloys capable of extending the life of parts used at high temperatures. For literature describing the properties of HAYNES high-temperature alloys, get in touch with the nearest Haynes Stellite Company Office.

HAYNES TRADE-MARK ALLOYS

HAYNES STELLITE COMPANY

A Division of Union Carbide and Carbon Corporation

UCC

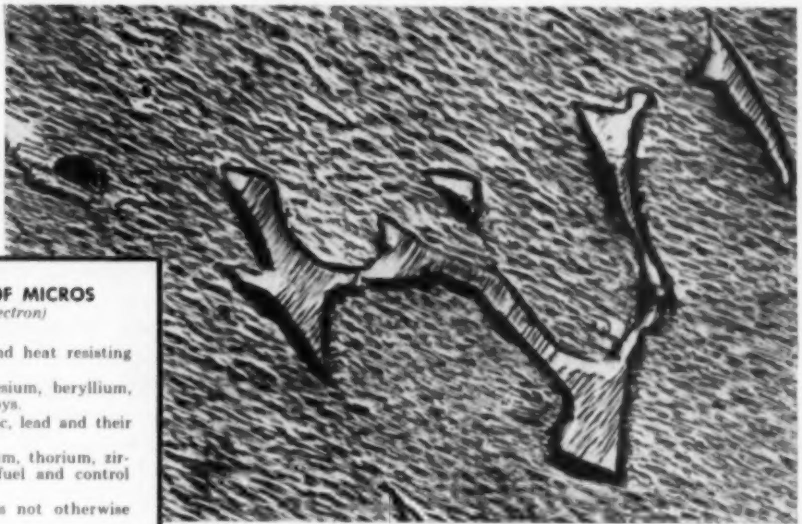
General Offices and Works, Kokomo, Indiana

Sales Offices

Chicago • Cleveland • Detroit • Houston • Los Angeles • New York • San Francisco • Tulsa

"Haynes" and "Multimet" are registered trade-marks of Union Carbide and Carbon Corporation.

11th Metallographic Exhibit



CLASSIFICATION OF MICROS
(Optical and Electron)

Class 1. Irons and steels.
Class 2. Stainless steels and heat resisting alloys.
Class 3. Aluminum, magnesium, beryllium, titanium and their alloys.
Class 4. Copper, nickel, zinc, lead and their alloys.
Class 5. Uranium, plutonium, thorium, zirconium and reactor fuel and control elements.
Class 6. Metals and alloys not otherwise classified.
Class 7. Series showing transitions or changes during processing.
Class 8. Welds and other joining methods.
Class 9. Surface coatings and surface phenomena.
Class 10. Results by unconventional techniques (other than electron micrographs)
Class 11. Slags, inclusions, refractories, cermets and aggregates
Class 12. Color prints in any of the above classes (no transparencies accepted)

Entries are invited in the 11th ASM Metallographic Exhibit, to be held at the National Metal Exposition in Cleveland, Oct. 6 through 12, 1956.

RULES FOR ENTRANTS

Work which has appeared in previous metallographic exhibits held by the American Society for Metals is unacceptable. Photographic prints should be mounted on stiff cardboard; maximum dimensions 14 by 18 in. (35 by 45 cm.) Heavy, solid frames are unacceptable. Entries should carry a label on the *face* of the mount giving:

Classification of entry
Material, etchant, magnification
Any special information as desired

The name, company affiliation and postal address of the exhibitor should be placed on the *back* of the mount.

Entrants living outside the U. S. A. should send their micrographs by first-class letter mail endorsed "Photo for Exhibition—May be opened for customs inspection".

Exhibits must be delivered before Oct. 1, 1956, either by prepaid express, registered parcel post or first-class letter mail, addressed to:

ASM Metallographic Exhibit
7301 Euclid Ave.
Cleveland 3, Ohio

AWARDS AND OTHER INFORMATION

A committee of judges will be appointed by the Metal Congress management which will award a First Prize (a medal and blue ribbon) to the best in each classification. Honorable Mentions will also be awarded (with appropriate medals) to other photographs which, in the opinion of the judges, closely approach the winner in excellence. A Grand Prize, in the form of an engrossed certificate and a money award of $100, will also be awarded the exhibitor whose work is judged best in the show, and his exhibit shall become the property of the American Society for Metals for preservation and display in the Society's national headquarters in Cleveland.

All photographs may be retained by the Society for one year and placed in a traveling exhibit to the various Chapters. They will be returned to the owners in May 1957 if so desired.

38TH NATIONAL METAL CONGRESS AND EXPOSITION

CLEVELAND, OHIO **OCTOBER 6 to 12, 1956**

Metal Progress

Taylor Lyman, *Publisher*

A. P. Ford, *Sales Manager*

George H. Loughner, *Production Manager*
7301 Euclid Ave., Cleveland 3—UTah 1-0200

District Managers

John B. Verrier, Jr. and James P. Hontas
342 Madison Ave., Room 1228, New York 17—CHickering 4-2713

William J. Hilty
7301 Euclid Ave., Cleveland 3—UTah 1-0200

C. Robert Bilbrey
53 West Jackson Blvd., Chicago 4, Ill.—WAbash 2-7822

Donald J. Walter
20050 Livernois St., Detroit 21, Mich.—University 4-3861

PUBLISHED BY AMERICAN SOCIETY FOR METALS, 7301 EUCLID AVE., CLEVELAND 3, OHIO—W. H. EISENMAN, SECRETARY

• Index to Advertisers •

KABLE PRINTING CO.

EF Furnaces for Bright Annealing and Normalizing ---- Continuously

Installation of five EF special atmosphere continuous furnaces bright annealing stainless steel wire.

For Wire, Tubing, Strip and other Products

3000 lbs. of steel tubing, per hour, are bright normalized in this EF gas-fired radiant tube type special atmosphere furnace.

We are in position to design, build and put in operation: continuous equipment for hot or cold rolled, high or low carbon, stainless, silicon, tin-plate, aluminum, brass, bronze or any other ferrous or non-ferrous metal—for bright annealing, normalizing, galvanizing, aluminizing, tinning or any other process—in the size and type best suited to your plant, process, product or production requirements. No job is too large or too unusual.

Put your production furnace problems up to experienced engineers—*it pays.*

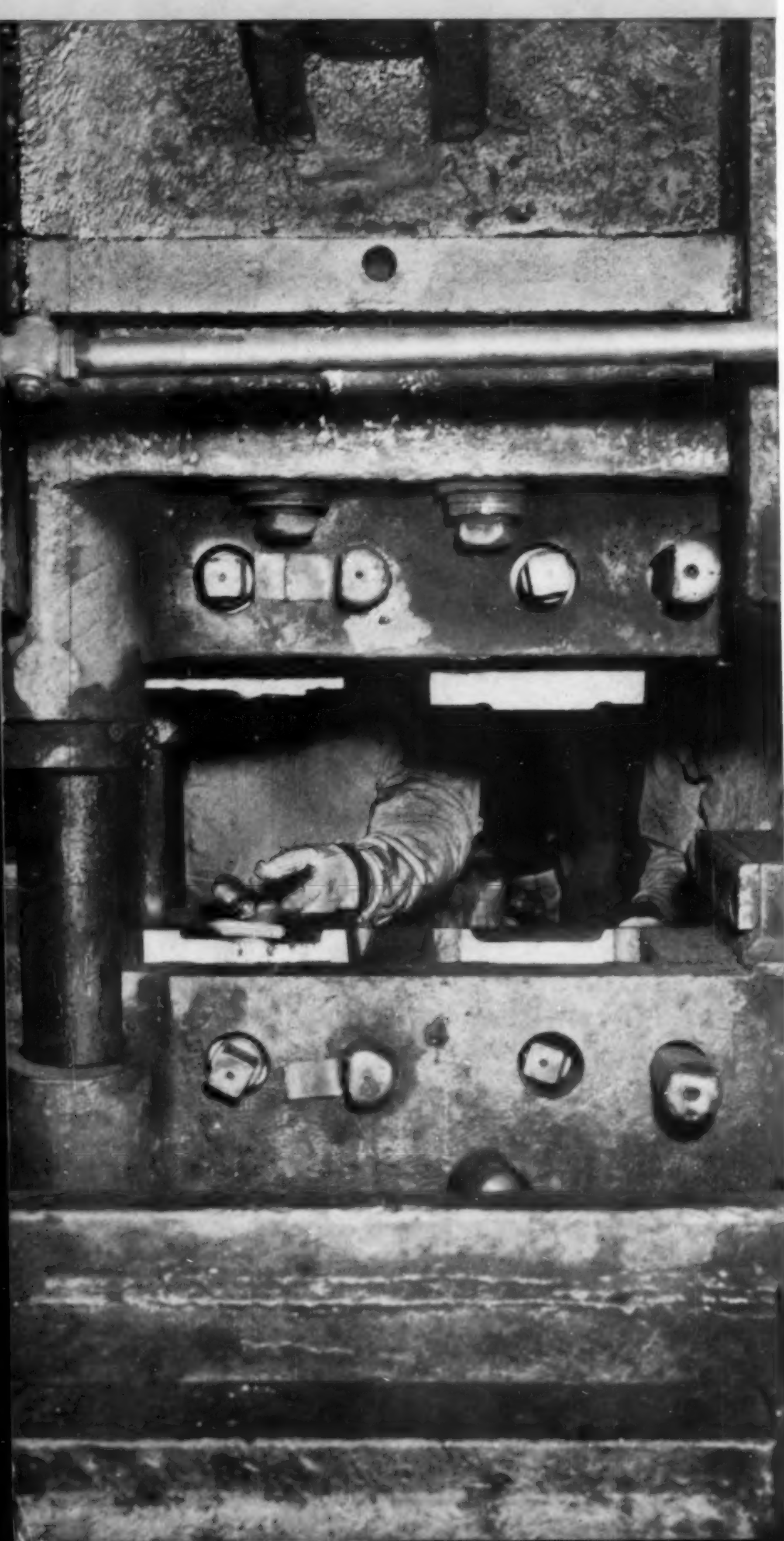
THE ELECTRIC FURNACE CO.
Salem • Ohio

EF *Gas Fired, Oil Fired and Electric Furnaces*

Canadian Associates • CANEFCO LIMITED • Toronto 1, Canada

A large capacity continuous strip normalizing, annealing and galvanizing unit. This is a combination EF gas fired radiant tube and electrically heated installation

'dag' dispersions . . . *a touch does so much!*



Colloidal Graphite saves $25,000 a year on jet-blade forging

In the close-limit forging of a jet-turbine blade, a prominent manufacturer found that by using **'dag'** Colloidal Graphite on the dies, only one blow was needed to go from upset billet to final blade shape. Besides eliminating the second hammer-blow previously required, intermediate descaling and reheating operations were also avoided . . . for a total yearly saving of some $25,000 on this single operation.

Both oil-based and water-based **'dag'** Colloidal Graphite dispersions are widely used in forging operations. Diluted and sprayed on the dies, the colloidal graphite forms a slick lubricating film . . . protects the expensive dies and improves metal flow during forging.

Pretreatment of new dies with **'Aquadag'** — colloidal graphite dispersed in water — has paid off handsomely, too. Some firms estimate a 50% greater usable life from forging dies given this protective film of colloidal graphite before being put into service.

The benefits of **'dag'** dispersions for forging and other metalworking applications are discussed in Bulletin 426. Ask for your free copy.

100th Anniversary

ACHESON COLLOIDS COMPANY

PORT HURON, MICHIGAN

. . . also Acheson Colloids Ltd., London, England

ACHESON COLLOIDAL DISPERSIONS:
Graphite • Molybdenum Disulfide • Zinc Oxide
Mica and other solids.

Acheson Colloids Company
Port Huron, Michigan, Dept. C-8

Yes, I want your free bulletin describing 'dag' Dispersions for Metalworking.

Name____________________

Title____________________

Company____________________

Address____________________

City__________ State__________